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USER'S GUIDE FOR THE TEST AND EVALUATION SECTIONS OF MIL-H-46855

BOEING Aerospace Company
Logistics Support and Services
Seattle, Washington 98124

June 30, 1977

Prepared for
Naval Air Development Center
Warminster, Pennsylvania 18974

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Assistance is provided to HF engineers in planning, scheduling, and performing HFE T&E in accordance with the requirements of MIL-H-46855. All appropriate aspects of the total HFE T&E process are indicated with emphasis being given to 33 HFE T&E techniques which may be used. Details of technique selection and use are included along with technique samples where appropriate. (--AD045 098)

The emphasis of this guide (as compared to the Navy manager's guide) is placed on the HFE evaluator's task of performing the most cost effective total T&E

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20. effort. Both formal and technical T&E program requirements are indicated. Basic T&E considerations such as data inputs, level of detail, timing, and applications are detailed. Types of HFE T&E are indicated and a system for evaluating and categorizing techniques is presented. The techniques included are both automatic and manual; these are further divided into groups of direct, indirect, automatic recording, physiological, and simulation. A fold-out chart, which integrates much of the guide content into an HFE evaluator's decision tree, is provided and may be used as a checklist to assist him in his tasks.

Included in the appendices is a list of personnel surveyed to obtain much of the guide material. Also included is a set of worksheets which contain details not covered in the main body of the guide.

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PREFACE

This guide is the result of work conducted under Naval Air Development Center Contract No. N62269-76-C-0434 between 1 July 1976 and 30 June 1977. Whereas the objective of this User's Guide is to clarify and expand on the test and evaluation sections of MIL-H-46855, this is only one phase of an effort to develop user's guides for the major portions of MIL-H-46855. Phase I, which was completed June 1976, covered the analysis portions of MIL-H-46855.

The author is indebted to the following persons for their guidance and contributions:

CDR Paul R. Chatelier, Naval Air Systems Command
Dr. Lloyd Hitchcock, Naval Air Development Center
Mr. Ed L. Holshouser, Pacific Missile Test Center
LCDR William F. Moroney, Pacific Missile Test Center

Within the Boeing Aerospace Company, the program was directed by Mr. W. J. Hebenstreit of Logistics Support and Services' Crew Systems Organization. Other Boeing personnel whose consultation during the program contributed significantly to the information contained herein include: Mr. D. W. Jahns, Dr. G. R. Gardlin, and Mr. M. M. Nagata.

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1.0 INTRODUCTION

During the course of system development, test and evaluation (T&E) is required to assure that the evolving system meets a myriad of requirements ranging from reduction of technical risks through demonstrating the system's military utility. Generally, two broad categories of test and evaluation are used (Reference 1): Development Test and Evaluation (DT&E) and Operational Test and Evaluation (OT&E), where the former is planned, conducted, and monitored by the Developing Agency (DA) of the system, and the latter is the responsibility of the Operational Test and Evaluation Force (OPTEVFOR). A third category, Production Acceptance Test and Evaluation (PAT&E), is testing conducted on production items to demonstrate that systems meet contract requirements and specifications.

The first two categories of T&E are defined in Reference 1 as follows:

> "DT&E is that test and evaluation conducted to: demonstrate that the engineering design and development process is complete; demonstrate that the design risks have been minimized; demonstrate that the system will meet specifications; and estimate the system's military utility when introduced..."

> "OT&E is that test and evaluation conducted to estimate the prospective system's military utility, operational effectiveness, and operational suitability (including compatibility, interoperability, reliability, maintainability, and logistic and training requirements), and need for modifications. In addition, OT&E provides information on organization, personnel requirements, doctrine, and tactics. Also, it may provide data to support or verify material in operating instructions, publications, and handbooks..."

Human factors engineering (HFE) is an extremely important aspect of the total T&E effort. HFE T&E must be established to:

a) demonstrate conformance of system, equipment and facility design to human engineering design crtieria;

b) confirm compliance with performance requirements where man is a performance determinant;

c) secure quantitative measures of system performance which are a function of man-machine interaction; and

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[1] OPNAVINST 3960.10. Department of the Navy. Office of the Chief of Naval Operations, "Test and Evaluation", Washington, D. C., October 1975.

d) determine whether undesirable design or procedural features have been introduced.

1.1 Purpose of the Guide

The objective of this guide is to provide assistance to human factors (HF) engineers in the planning, scheduling, and performance of human factors engineering (HFE) T&E in accordance with the requirements of MIL-H-46855 (Reference 2). The requirements of Paragraphs 3.2.4 through 3.2.4.3 of MIL-H-46855 are interpreted and delineated in terms of the HFE T&E steps and techniques which need to be performed. This guide will help to ensure that the HF engineer includes all appropriate aspects of the total HFE T&E process in system development efforts.

There has been a long standing need for both this type of guide and for a guide which provides assistance to human factors engineering (HFE) analysts in performing the analysis portion of their engineering activities. The analyst's guide (Reference 3) has been prepared as the first phase of a total effort to amplify and interpret the requirements of MIL-H-46855.

The particular need for this T&E guide has been to select effectively, for a given type of program, just which HFE T&E techniques should be performed, when and how to perform them, how their results will be used, and what their relative cost will be. These technique selection criteria enable the HF engineer to develop realistic, objective planning within the monetary and time constraints of a program. This document provides guidelines for the HF engineer that are based on both Navy and industry surveys of T&E experience and needs. The guide lists and explains the criteria for choosing various T&E techniques. It provides the basis for matching particular techniques to particular applications, and it describes in detail how to use the various techniques.

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[2] MIL-H-46855A, Human Engineering Requirements for Military Systems, Equipment and Facilities, 2 May 1972.

[3] Geer, C. W., Analyst's Guide for the Analysis Sections Sections of MIL-H-46855, D180-19476-1, Boeing Aerospace Company, Naval Air Development Center, June 1976.

This guide may be used at all levels of program design and procurement, including analysis; however, it is designed more specifically for the HF engineer to use during the later design development test and evaluation stages.

1.2 Scope of the Guide

This document assumes user knowledge of basic HFE concepts. It presents the significant aspects of HFE T&E alone rather than material on the complete field of human factors engineering. A complete description of human factors engineering as well as its typical applications and value may be found in any of several HFE text books.

This guide contains a detailed description of specific HFE T&E tasks and techniques. It indicates how to go about implementing or using these tasks and techniques and the best time to use them. Comments are included regarding technique selection and usefulness. In many instances, examples of particular techniques are also presented.

The guide will be of use in responding to RFP's (Request for Proposals) and in the preparation of HFE Test and Evaluation Plans and HFE Program Plans in particular. A program planning decision tree checklist for HFE observers/evaluators is included in Section 2.3 of this guide. This decision tree checklist indicates the decisions to be made and actions to be taken in responding to an RFP or during the performance of the MIL-H-46855 T&E effort.

A similar guide to this has been prepared for use by Navy managers (Reference 4). It includes most of the same material; the major difference is in the detail presented in the sections on HFE T&E tasks and techniques. The section on program planning in the Navy Manager's Guide is modified appropriately to the manager's point of view.

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[4] Geer, C.W., Navy Manager's Guide for the Test and Evaluation Sections of MIL-H-46855, D194-1006-2, Boeing Aerospace Company, Naval Air Development Center, June 1977.

In Appendix A there is a list of all the various organizations that were contacted in order to determine the kinds of data which should be contained in the two guides. These individuals were interviewed directly as to their T&E experience, problems, and needs.

The appendices also contain information on definitions/acronyms pertaining to this guide, and the T&E sections of MIL-H-46855. Appendix D is a complete package of T&E technique worksheets. These worksheets were prepared from data obtained from survey of individuals listed in Appendix A and through a survey of available literature. The worksheets were prepared primarily for the purpose of gathering data for the narrative descriptions of each of the techniques in Section 5.0. However, the worksheets will be of direct use for technique comparisons.

2.0 HFE TEST AND EVALUATION APPROACH

This section of the guide describes a general approach to the HFE T&E effort. It includes both the formal and the practical (or technical) reasons for performing HFE T&E. The approach to this HFE T&E effort is detailed by a program planning decision tree diagram and by a section describing the basic HFE T&E technique considerations of a) data inputs, b) timing, c) level of evaluation detail, d) evaluator's judgment, and e) evaluation applications.

2.1 Formal Requirements

The formal requirements for performing test and evaluation are found in certain Department of Defense (DoD) directives and SECNAV (Secretary of Navy), NAVMAT (Chief of Navy Material), and OPNAV (Chief of Naval Operations) instructions. The particular formal requirements for HFE and HFE T&E, are found in NAVMATINST 3900.9 (Reference 5). Additional requirements for HFE T&E are also found in MIL-H-46855. Two Data Item Descriptions (DID's) have been developed for use in performing HFE T&E. There are also several guides, handbooks, and general literature sources on the subject of HFE T&E. Some of the most important formal HFE T&E requirements are always to be found in the program contract, including the system specification and statement-of-work. While the military is largely controlled by directives and instructions, contractors are controlled by military specifications/standards and DID's. Guides, handbooks, general literature and the attitudes of both the procurement agency and contractor tie military and contractor HFE T&E efforts together.

2.1.1 T&E Directives and Instructions

In 1971, the Deputy Secretary of Defense promulgated the policy for major defense system acquisition via DoD Directive 5000.1, "Major Systems Acquisition" (Reference 6). Included within this directive is the

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[5] NAVMATINST 3900.9, Department of Navy, Headquarters Naval Material Command, "Human Factors", Washington, D. C. 20360, September 1970.

[6] DoD Directive 5000.1, Department of Defense, "Major System Acquisition", Washington, D.C. 20301, January 1977.

requirement to formalize and incorporate T&E into the early program development stages. This directive also required the Navy to upgrade and expand T&E of all weapon systems to include testing in a simulated combat environment as a prerequisite for procurement. SECNAVINST 5000.1 implemented this system acquisition policy within the Navy. Reference 7 presents the Defense System Acquisition Review Council (DSARC) review requirements for weapons systems acquisition, and translates the review checklists (DSARC milestones) into HFE requirements.

DoD Directive 5000.3, "Test and Evaluation" (Reference 8) establishes policy for the conduct of test and evaluation by the Military Departments and Defense Agencies. It directs the developing agency of the DoD component to initiate T&E as early as possible and to continue throughout the system acquisition process as necessary to assist in progressively reducing acquisition risks and in assessing military worth. In addition, DoD Directive 5000.3 requires that the acquisition schedules be based upon accomplished T&E milestones prior to the time key decisions are to be made, which would commit significant additional resources.

NAVMATINST 3960.6, "Planning and Implementation of Tests and Evaluations of New Weapon Systems", (Reference 9) provides guidance for the planning and implementation of tests and evaluations required as a part of the system acquisition process. This instruction provides guidance for preparing the Test and Evaluation Master Plan (TEMP).

OPNAVINST 3960.10, "Test and Evaluation", (Reference 1) establishes policies for T&E in Navy acquisition programs and defines T&E responsibilities

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[7]Holshouser, E. L., Translation of DSARC Milestones into Human Factors Engineering Requirements, Pacific Missile Test Center, Point Mugu, Calif., 93042, TP-45-58, AD-3006927L, September 1975.

[8]DoD Directive 5000.3, Department of Defense, "Test and Evaluation", Washington, D. C. 203-1, January 1973.

[9]NAVMATINST 3960.6, Department of Navy, Headquarters Naval Material Command, "Planning and Implementation of Tests and Evaluations of New Weapons Systems", Washington, D. C. 20350, August 1973.

for various organizations. It establishes procedures for planning, conducting, and reporting T&E. It describes the relationship between developmental and operational T&E and it establishes procedures and a format for test and evaluation master plans (TEMP's). It also establishes procedures for obtaining fleet RDT&E (Research Development Test and Evaluation) Research and Development (R&D) that is not part of an acquisition program. Three distinct phases of T&E are defined by this instruction. The relationship between these phases is discussed in Section 3.0.

NAVMATINST 3900.9, "Human Factors", establishes policies and requirements necessary to insure adequate development of human factors aspects of systems and equipment. This includes all development, test and evaluation, and production programs and projects. This instruction states that the human element of the Navy systems shall undergo the same development, test and evaluation steps as equipment elements of the same system.

2.1.2 Military Specifications and Standards

The primary source for contractor HFE T&E requirements is MIL-H-46855. A copy of the sections pertinent to analysis is contained in Appendix C. Figure 2.1-1 shows each of the major MIL-H-46855 sections in functional relation to each other. Section 3.2.4 "Perform HE Test and Evaluation" is the function/section most pertinent to this guide. It is divided into three subsections: planning, implementation, and failure analysis. Unless otherwise contractually noted, Section 3.2.4 and its subsections are the detailed requirements in MIL-H-46855 necessary to provide an adequate HFE T&E program. The major paragraph, 3.2.4, indicates most of the tasks that the contractors must perform. Paragraph 3.2.4.1 (Planning) emphasizes the need for HFE tests integrated along with other system tests in order to save the cost/duplication of completely separate testing. Early testing, in accordance with this paragraph will also save the cost of unnecessary late system rework. Paragraph 3.2.4.2 (Implementation) contains a list of test tasks to be performed in order to insure a complete HFE T&E program. Paragraph 3.2.4.3 (Failure Analysis) emphasizes the need to investigate human error. HFE T&E techniques listed in later sections of this guide may be used to accomplish this requirement for human failure analysis.

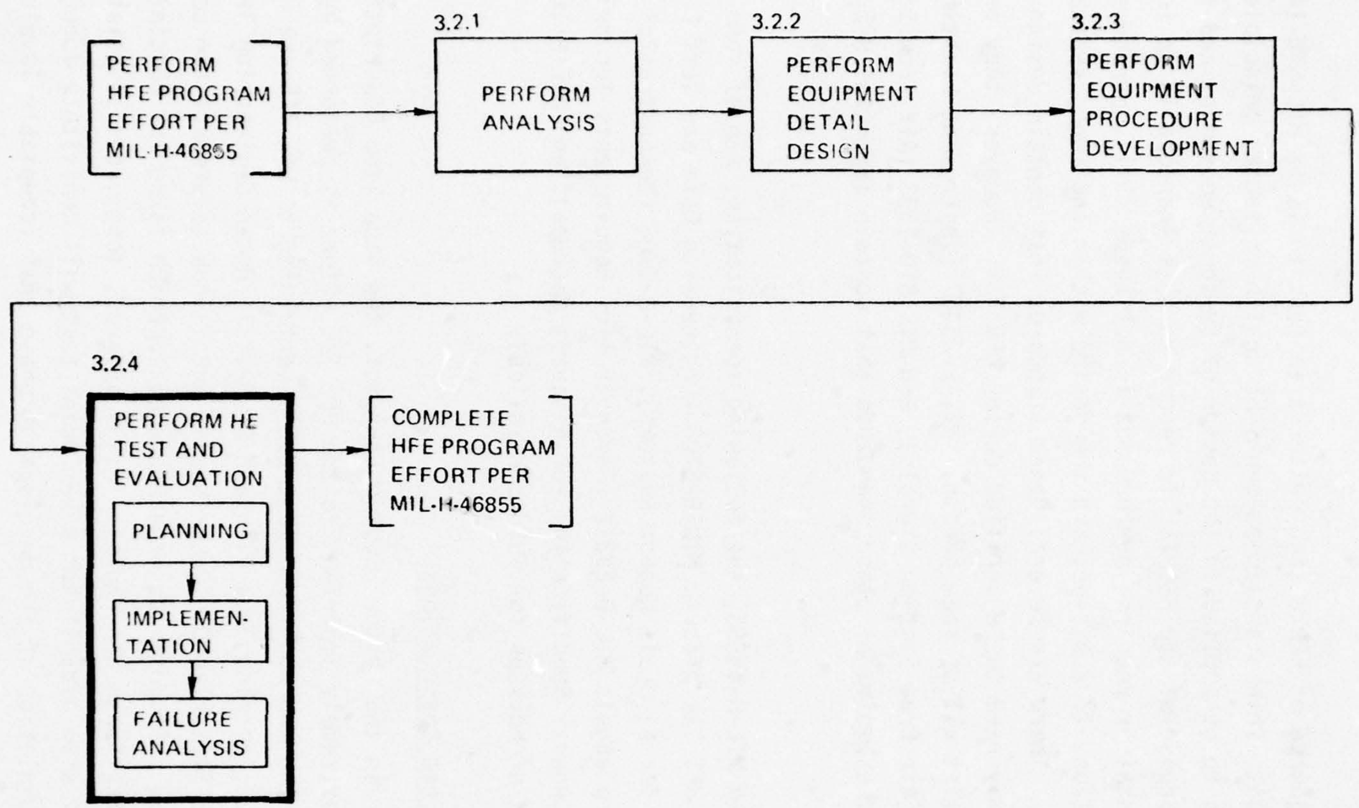

Figure 2.1-1, MIL-H-46855 Section Functional Relationships

The Primary source of HFE design criteria to test to is in MIL-STD-1472 (Reference 10). This standard presents HE design criteria, principles, and practices to be applied in the design of systems, equipment and facilities. The purpose of the HFE T&E in regard to this standard is to insure: operator/maintainer required performance is achieved; skill, personnel-equipment combinations is achieved; and the design within and among systems is standardized. There are several other standards that contain design criteria which may need to be verified during HFE T&E. However, they are too numerous to list all of them herein. MIL-L-25467 (Instrument Lighting), MIL-STD-411 (Air Crew Station Signals), and MIL-STD-1333 (Air Crew Station Geometry) are examples of other standards that contain important HFE design criteria.

In addition to MIL-H-46855, the following specifications are of some importance to the HFE T&E effort: MIL-D-8706 (Engineering Data and Test Contract Requirements for Aircraft Weapon Systems); MIL-D-8708 (Demonstration Requirements for Airplanes); MIL-D-23222 (Demonstration Requirements for Helicopters); MIL-M-8650 (General Specification for Aircraft Mockups); and MIL-M-18828 (Construction of Mockups for Guided Missiles).

2.1.3 Data Item Descriptions

If called for in the system program contract, the Data Item Descriptions (DID's) are extremely important to the HFE T&E effort as performed by the contractor. The two most important DID's pertaining to HFE T&E are DI-H-2105, Human Engineering Test Plan and DI-H-2111, Human Engineering Test Report. The HE Test Plan DID describes in detail how to prepare the contractor's test plan. It describes the proposed approach taken for obtaining T&E data. It establishes and explains all standards, tests, and associated analyses. It also establishes other means that will constitute adequate proof upon completion of the development phase that acceptable levels of

[10] MIL-STD-1472B, Human Engineering Design Criteria for Military Systems, Equipment and Facilities, 31 December 1974.

human performance, time, accuracy, and safety factors can be achieved in operational use under specified manning levels. Reference 11 is particularly helpful in preparing the HF Test Plan. The HE Test Report DID describes how to prepare the documentation associated with contractor tests. The test report is to be used by the procuring activity to assure that the man-equipment interface requirements for the operation and maintenance of the system conform to the contractual requirements.

2.1.4 Guides, Handbooks, and General Literature

This category of HFE T&E requirements is by far the most voluminous, and it includes several data sources of note. The Department of the Navy RDT&E Management Guide (Reference 12) is a good source of general Integrated Logistics Support (ILS) T&E requirements. Reference 13 is an excellent summary of policy and procedures for HFE T&E which can serve as a useful guide for gaining an overview of the scope of the HFE T&E effort. Reference 14, Human Factors Evaluation in System Development, is an excellent textbook source for HFE T&E data. General theory as well as data collection and analysis methods are thoroughly presented.

The Air Force Human Resources Laboratory has prepared a report (Reference 15) which reviewed 95 documents related to Personnel Subsystem Test and Evaluation (PSTE). Each report was abstracted and then analyzed in terms of 11 categories: a) Scope and relation to HF elements; b) Test objectives; C) Data requirements and test criteria; d) Data collection methodology; e) Support

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[11] Holshouser, E. L., Guide to Human Factors Engineering General Purpose Test Planning (GPTP), Pacific Missile Test Center, Point Mugu, Calif., 93042, 1st Iteration, September 1976.

[12] Department of the Navy Management Guide, NAVSO P-2457 (Rev. 1-75), 1 January 1975.

[13] Holshouser, E. L., Human Factors Engineering Policy and Procedures for Test and Evaluation of Navy Systems, TP-75-15, Pacific Missile Test Center, AD-B006035L, July 1975.

[14] Meister, D., and Rabideau, G. F., Human Factors Evaluation in System Development, John Wiley and Sons, New York, 1965.

[15] Askren, W. B., and Newton, R. R., Review and Analysis of Personnel Subsystem Test and Evaluation Literature, AFHRL-TR-68-7, AFHRL, AFSC, W-PAFB, January 1969.

requirements; f) Reducing and analyzing data; g) Significant test results; h) Communicating and using test results; i) Factors in planning a test program; j) Factors in conducting a test program; and k) Other problems. Included among the several excellent references within the AFHRL report are three particularly useful documents:

a) The first report (Reference 16) is prepared by the Aerospace Medical Research Laboratories. It describes the practices and evaluative aspects of human performance assessment in Air Force systems. The human performance test program for 34 systems and subsystems representing the major types of systems used by the Air Force were reviewed.

b) The Reference 17 guidebook was developed as an aid for the Project Officer in the assessment of human factors effects on system performance and in the isolation of causal factors. Included in this guide are the tools and techniques for system evaluation. This includes methods for obtaining time, accuracy, and maintenance data as well as the techniques for analyzing and interpreting these data. A detailed example of the application of the techniques is included.

c) Reference 18 is a good review of the problems associated with field testing of human performance and the resulting subjectively-oriented data collection techniques. Factors to be considered in the planning of field tests were also discussed.

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[16] Keenan, J. J., et. al., Concepts and Practices in the Assessment of Human Performance in Air Force Systems, AMRL-TR-168, AD 625 041, Aerospace Medical Research Laboratories, W-PAFB, September 1965.

[17] Myers, L. B., et. al., Guidebook for the Collection of Human Factors Data, Report PTB 66-3, AD 631 023, HRB - Singer, Inc., State College, Pennsylvania, January 1966.

[18] Rabideau, G. F., "Field Measurement of Human Performance in Man-Machine Systems", Human Factors, December 1964.

2.2 Technical Requirements

These are the important "real world" requirements such as design criteria, safety, training, and life support that the HFE observer/evaluator needs to ensure are verified as integral to the system design being evaluated. The system must meet these requirements in order to insure the adequacy of the man/machine interface. Table 2.2-1 lists each of these requirements in a matrix comparison with the techniques presented in Section 5.0. The purpose of this matrix is to quickly show which techniques may be used to test and evaluate the system in order to verify compliance with these technical requirements. Each of these technical requirements is presented in the following subsections along with a brief summary of the reasons for the importance of their test and evaluation.

2.2.1 Human Performance

All systems require a degree of human performance in order to function as specified. In order to meet system performance requirements such as speed, maneuverability, range or turnaround time, the operators and maintainers must meet certain minimum requirements for performing their assigned tasks. These requirements are most always in terms of time to perform a task or accuracy (or reliability) with which a task must be performed. The planned operator/maintainer task times and error rates must therefore be verified by HFE observation and test.

2.2.2 Design Criteria

Human engineering design criteria are the kinds of requirements contained in MIL-STD-1472 (Reference Section 2.1.2). The incorporation of these criteria into the hardware design insures a relatively high degree of operator/maintainer performance. These criteria are based on several years of experience as to the design features or details that tend to minimize operator errors or slow operator performance. Many of these design requirements are based on lab experiments and quantified comparative data. For each of the basic system functions, there should be certain HE criteria that should be incorporated into the design and should therefore be evaluated to insure its existence. General categories of HE design criteria include: displays, controls, labeling, workspace layout, and maintainability.

Table 2.2-1: HFE T&E Technical Requirements vs. Techniques

SPECIFIC HFE T&E TECHNIQUES/TOOLS	TECHNICAL REQUIREMENTS: PAGE REFERENCE	HUMAN PERFORMANCE	DESIGN CRITERIA	SAFETY	TRAINING	PERSONNEL SKILL/QUANTITY	TECHNICAL PUBLICATIONS	LIFE SUPPORT CRITERIA
MANUAL DIRECT:								
CONTINUOUS OBSERVATION	43	•	•	•	•	•	•	•
SAMPLED OBSERVATION	45	•	•	•	•	•	•	•
DESIGN CRITERIA CHECKLIST	46		•	•				•
SPEC COMP SUMMARY SHEET	49	•	•					•
T.O. FUNCT EVALUATION	52						•	
HPR TESTING	56	•						
HFTEMAN	58		•	•				•
G-2/G-5 ANTHROPOMETERS	60		•	•				
TERRAIN VISIBILITY DEF	61		•					
ENV & PERF MEAS. EQUIP.	65	•	•	•				•
MANUAL SYS MEASUREM'TS:								
SYSTEM RECORDS REVIEW	67	•		•	•	•	•	
HUMAN INITIATED FAILURES	69	•	•			•	•	
TEST PART. HISTORY RECORD	70				•	•		
MANUAL INDIRECT:								
INTERVIEWS	73	•	•	•	•	•	•	•
QUESTIONNAIRES	77	•	•	•	•	•	•	•
FUNCT DESC INV(FDI)	82			•	•	•		
PAARS	84	•				•	•	
COOPER-HARPER	85		•	•				
PROBLEM INCIDENT REP	89	•	•	•		•	•	•
AUTOMATIC RECORDING:								
MOTION PICTURES	92	•	•	•	•	•	•	•
SOUND TAPES	94	•	•	•	•	•	•	•
VIDEO TAPES	95	•	•	•	•	•	•	•
PHOTOGRAPHY	97	•	•	•	•	•	•	•
EVENT RECORDING	99	•						
OPREDS	103	•			•	•	•	
SECONDARY TASK MON.	109	•				•		
AUTOMATIC PHYSIOLOGICAL:								
PHYSIOLOGICAL INSTRUMENTAITON	110	•						•
PHYSICAL MEASUREMENT	113	•				•		
SIMULATION:								
CGE	116		•	•				
CAR	119		•	•				
CAPE	121		•					
FOVEA	125		•					
ONLINE INTERACTIVE	126	•			•	•	•	

2.2.3 Safety

This is a special category of design criteria that is listed here and in other documentation separately in order to add emphasis to its importance. As is the case with other design criteria, lab tests and experience have indicated that certain design requirements (e.g., rails on stairs) inherently increase the system safety.

2.2.4 Training

Depending on the organizational setup or "charter" of a particular HFE T&E group, the evaluation of test participant training may or may not be necessary by the HFE group. Certainly training is an important aspect of a total system test. All other HFE aspects may be properly provided for but improper training of participants may be sufficient cause to ruin an otherwise successful test. Training requirements may be evaluated in terms of type, duration, and detail.

2.2.5 Personnel Skill/Quantity

Closely associated with training is the test participant skill level. This is a combination of his training on other systems somewhat related to the present system being tested and his aptitude for the type of work he is performing. Quantity simply refers to the number of test participants performing each of the operator/maintainer tasks. The fact that the proper number, too many, or too few operators are assigned to a test task should be observed and reported.

2.2.6 Technical Publications

This technical requirement is similar to the training requirements in that it is often not the job of HFE observers to evaluate. However, technical publications (tech orders or job manuals) are a very important part of the total system under test. In most instances, test participants operate or maintain the system under test in accordance with procedures that have been developed for the particular system function. Just as it is necessary that

the prototype hardware be tested and evaluated, so must the "prototype" or preliminary technical publications be tested. This evaluation, which is sometimes referred to as validation/verification, should include how well the technical data meets the requirement to provide easily understandable and accurate procedural data. Technical narrative, diagrams, illustrations, and photographs should all be evaluated.

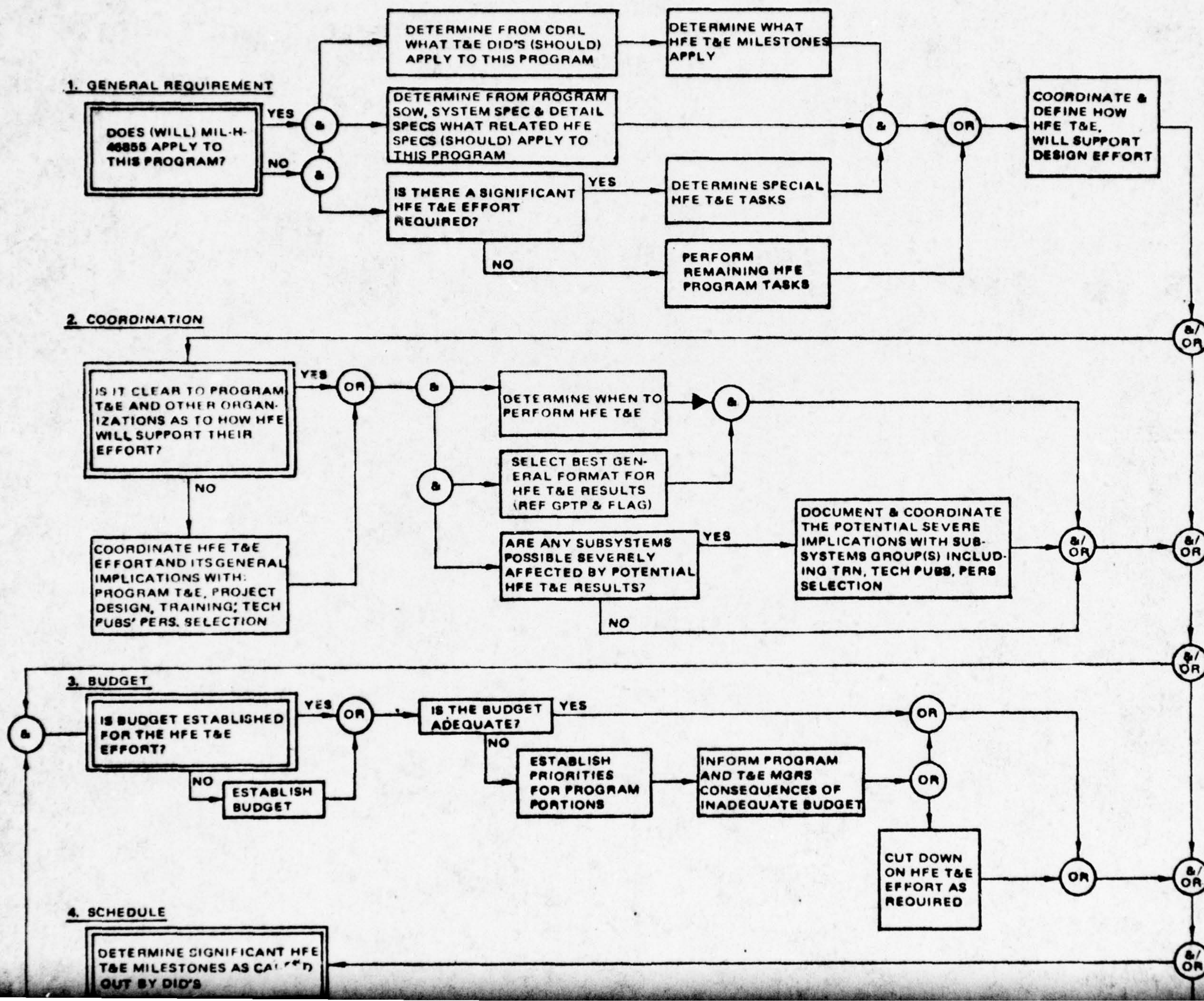
2.2.7 Life Support Criteria

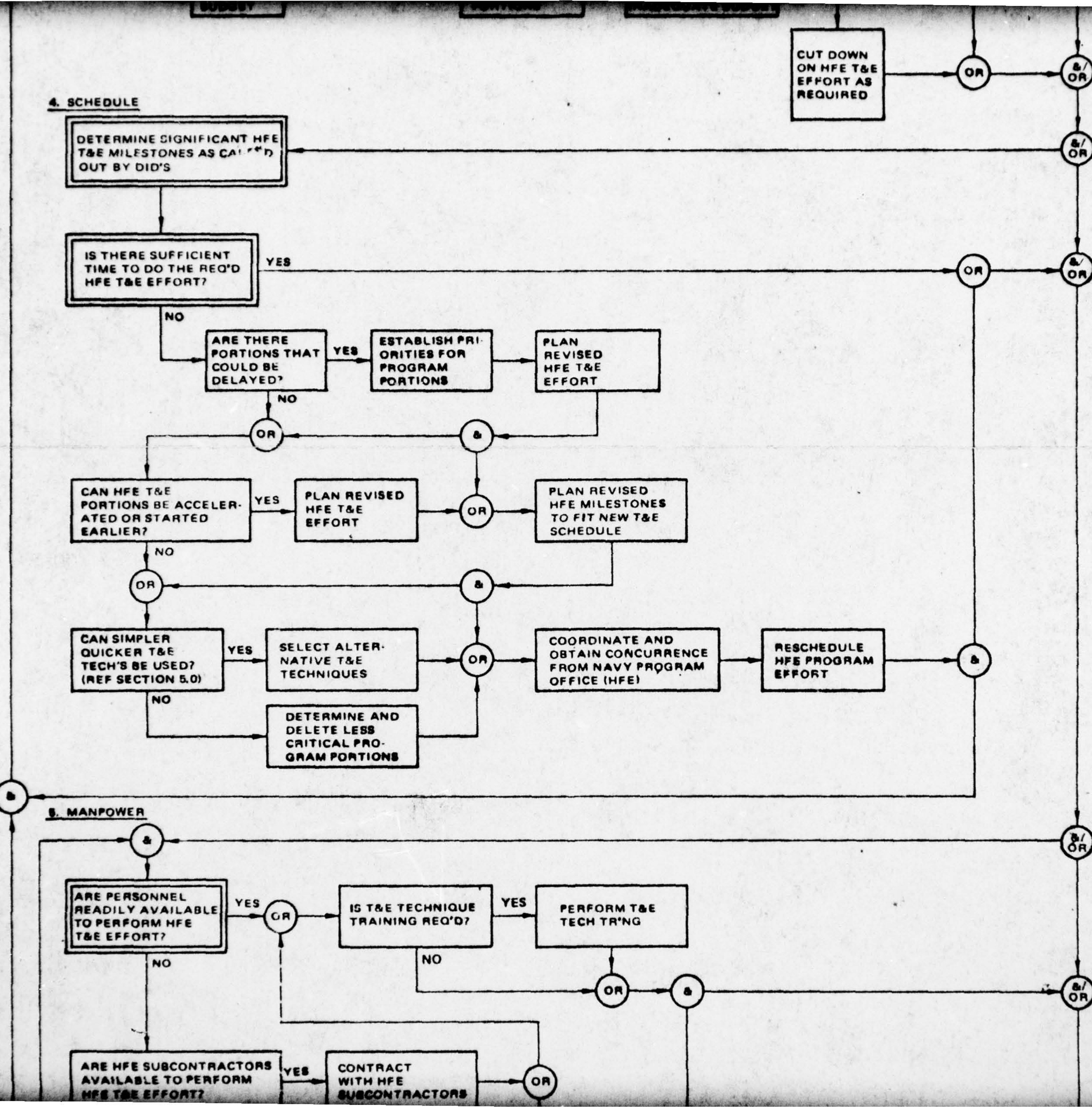
Life support criteria is another special category of design criteria. It is listed here separately from design criteria to add emphasis to these requirements. Life support requirements include: atmospheric conditions, noise, vibration, shock, toxicology, radiology, lighting, psychophysiology, fatigue, clothing, and personal equipment. In many man/machine system designs, life support requirements are relatively insignificant. However, in high performance systems and those requiring closed loop environmental control, life support requirements are particularly critical.

2.3 Decision Making Structure

There are a considerable number of decisions that must be made and actions taken by the HFE observer/evaluator during the HFE T&E program effort phase. The decision tree fold-out provided in this section of the guide (Figure 2.3-1) is designed to aid the HFE observer/evaluator in determining the proper decisions and actions. Its further purpose is to provide the HFE observer/evaluator with planning assistance and checklist items to ensure inclusion of all necessary tasks and data in the T&E program. This diagram is designed to be an adjunct to the General Purpose Test Planning (GPTP) (Reference 11) diagrams.

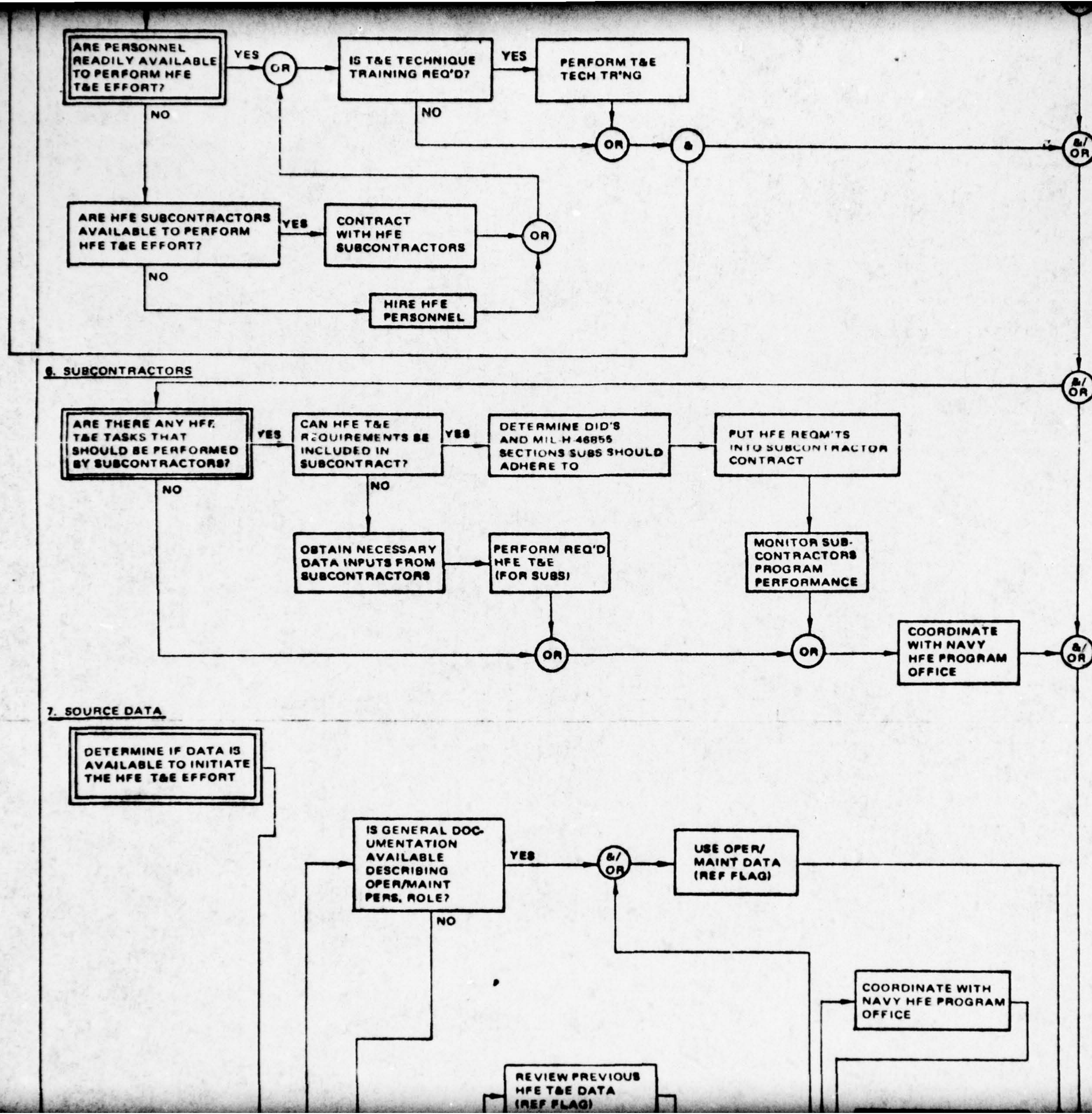
The Human Engineering Test Plan is developed as a result of specified program office requirements and Data Item Description (DID's) which are called out in program statements-of-work (SOW's). The GPTP indicates how to prepare this Human Engineering Test Plan which is the documentation of how the HFE effort will be accomplished. The GPTP diagrams are designed to assist the HFE observer/evaluator in preparing the HE test plan. The diagram in this section is intended to assist in all aspects of HFE T&E, particularly the initial phase of setting up an HFE T&E effort.

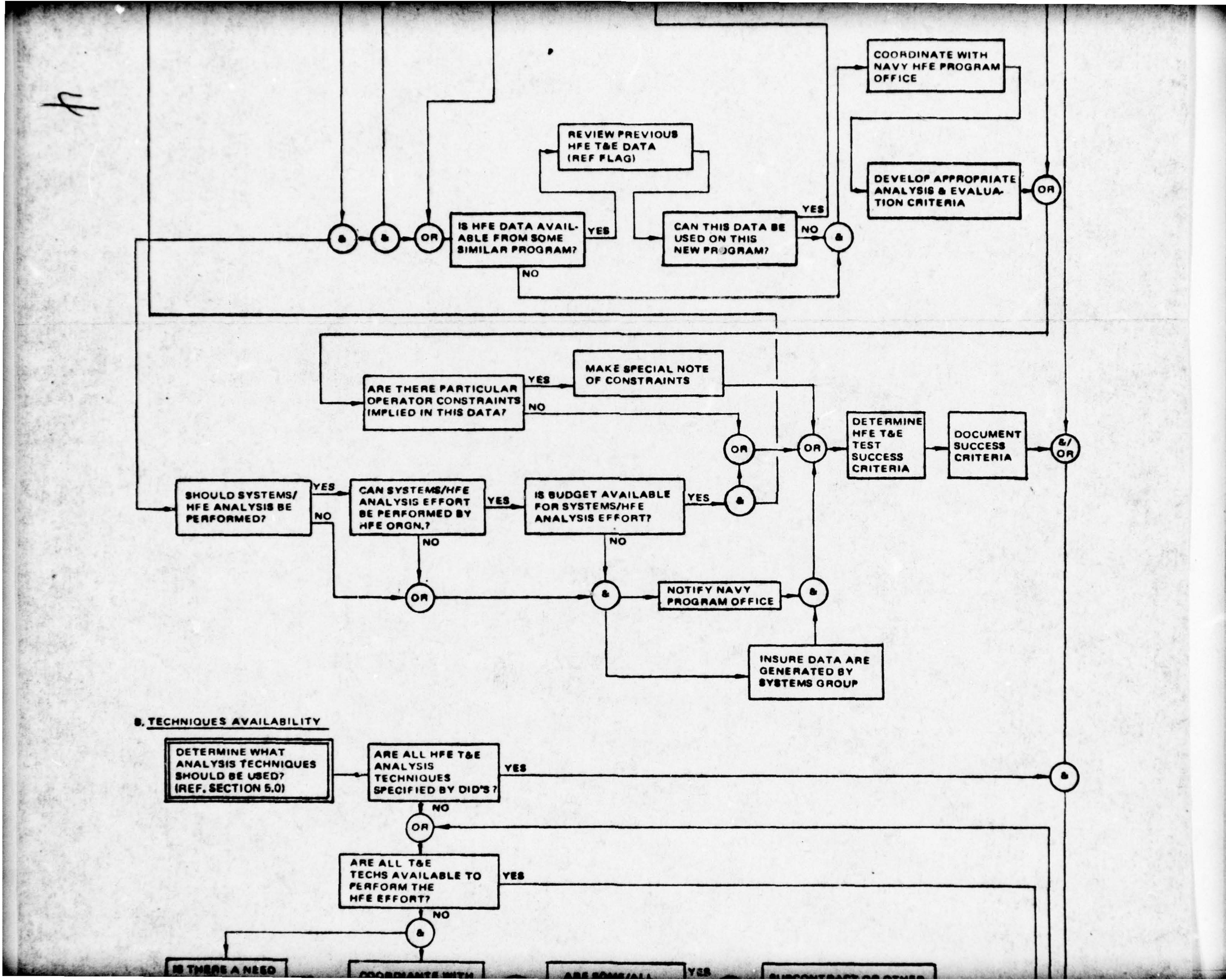

1. GENERAL REQUIREMENT
DOES (WILL) MIL-H-46855 APPLY TO THIS PROGRAM?
YES
NO
&
DETERMINE FROM CDRL WHAT T&E DID'S (SHOULD) APPLY TO THIS PROGRAM
DETERMINE WHAT HFE T&E MILESTONES APPLY
DETERMINE FROM PROGRAM SOW, SYSTEM SPEC & DETAIL SPECS WHAT RELATED HFE SPECS (SHOULD) APPLY TO THIS PROGRAM
IS THERE A SIGNIFICANT HFE T&E EFFORT REQUIRED?
DETERMINE SPECIAL HFE T&E TASKS
PERFORM REMAINING HFE PROGRAM TASKS
OR
COORDINATE & DEFINE HOW HFE T&E, WILL SUPPORT DESIGN EFFORT
&/OR
2. COORDINATION
IS IT CLEAR TO PROGRAM T&E AND OTHER ORGANIZATIONS AS TO HOW HFE WILL SUPPORT THEIR EFFORT?
COORDINATE HFE T&E EFFORT AND ITS GENERAL IMPLICATIONS WITH: PROGRAM T&E, PROJECT DESIGN, TRAINING; TECH PUBS' PERS. SELECTION
DETERMINE WHEN TO PERFORM HFE T&E
SELECT BEST GENERAL FORMAT FOR HFE T&E RESULTS (REF GPTP & FLAG)
ARE ANY SUBSYSTEMS POSSIBLE SEVERELY AFFECTED BY POTENTIAL HFE T&E RESULTS?
DOCUMENT & COORDINATE THE POTENTIAL SEVERE IMPLICATIONS WITH SUBSYSTEMS GROUP(S) INCLUDING TRN, TECH PUBS, PERS SELECTION
3. BUDGET
IS BUDGET ESTABLISHED FOR THE HFE T&E EFFORT?
ESTABLISH BUDGET
IS THE BUDGET ADEQUATE?
ESTABLISH PRIORITIES FOR PROGRAM PORTIONS
INFORM PROGRAM AND T&E MGRS CONSEQUENCES OF INADEQUATE BUDGET
CUT DOWN ON HFE T&E EFFORT AS REQUIRED
4. SCHEDULE
DETERMINE SIGNIFICANT HFE T&E MILESTONES AS CALLED OUT BY DID'S

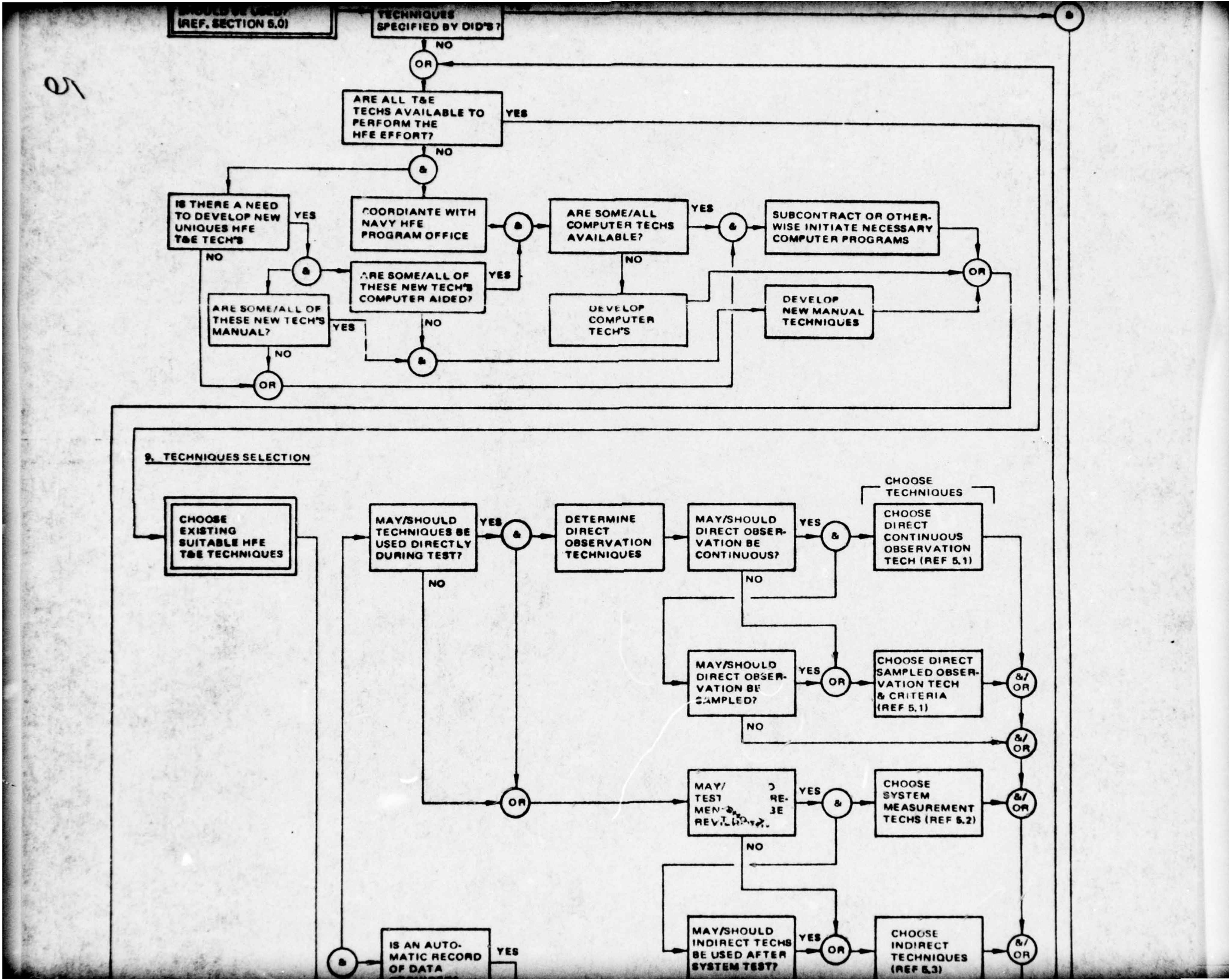


4. SCHEDULE
DETERMINE SIGNIFICANT HFE T&E MILESTONES AS CALLED OUT BY DID'S
IS THERE SUFFICIENT TIME TO DO THE REQ'D HFE T&E EFFORT?
YES
NO
ARE THERE PORTIONS THAT COULD BE DELAYED?
YES
NO
ESTABLISH PRIORITIES FOR PROGRAM PORTIONS
PLAN REVISED HFE T&E EFFORT
CAN HFE T&E PORTIONS BE ACCELERATED OR STARTED EARLIER?
YES
NO
PLAN REVISED HFE T&E EFFORT
PLAN REVISED HFE MILESTONES TO FIT NEW T&E SCHEDULE
CAN SIMPLER QUICKER T&E TECH'S BE USED? (REF SECTION 5.0)
YES
NO
SELECT ALTERNATIVE T&E TECHNIQUES
DETERMINE AND DELETE LESS CRITICAL PROGRAM PORTIONS
COORDINATE AND OBTAIN CONCURRENCE FROM NAVY PROGRAM OFFICE (HFE)
RESCHEDULE HFE PROGRAM EFFORT
CUT DOWN ON HFE T&E EFFORT AS REQUIRED
OR
&/OR
&
5. MANPOWER
ARE PERSONNEL READILY AVAILABLE TO PERFORM HFE T&E EFFORT?
YES
NO
IS T&E TECHNIQUE TRAINING REQ'D?
YES
NO
PERFORM T&E TECH TR'NG
ARE HFE SUBCONTRACTORS AVAILABLE TO PERFORM HFE T&E EFFORT?
YES
CONTRACT WITH HFE SUBCONTRACTORS

2

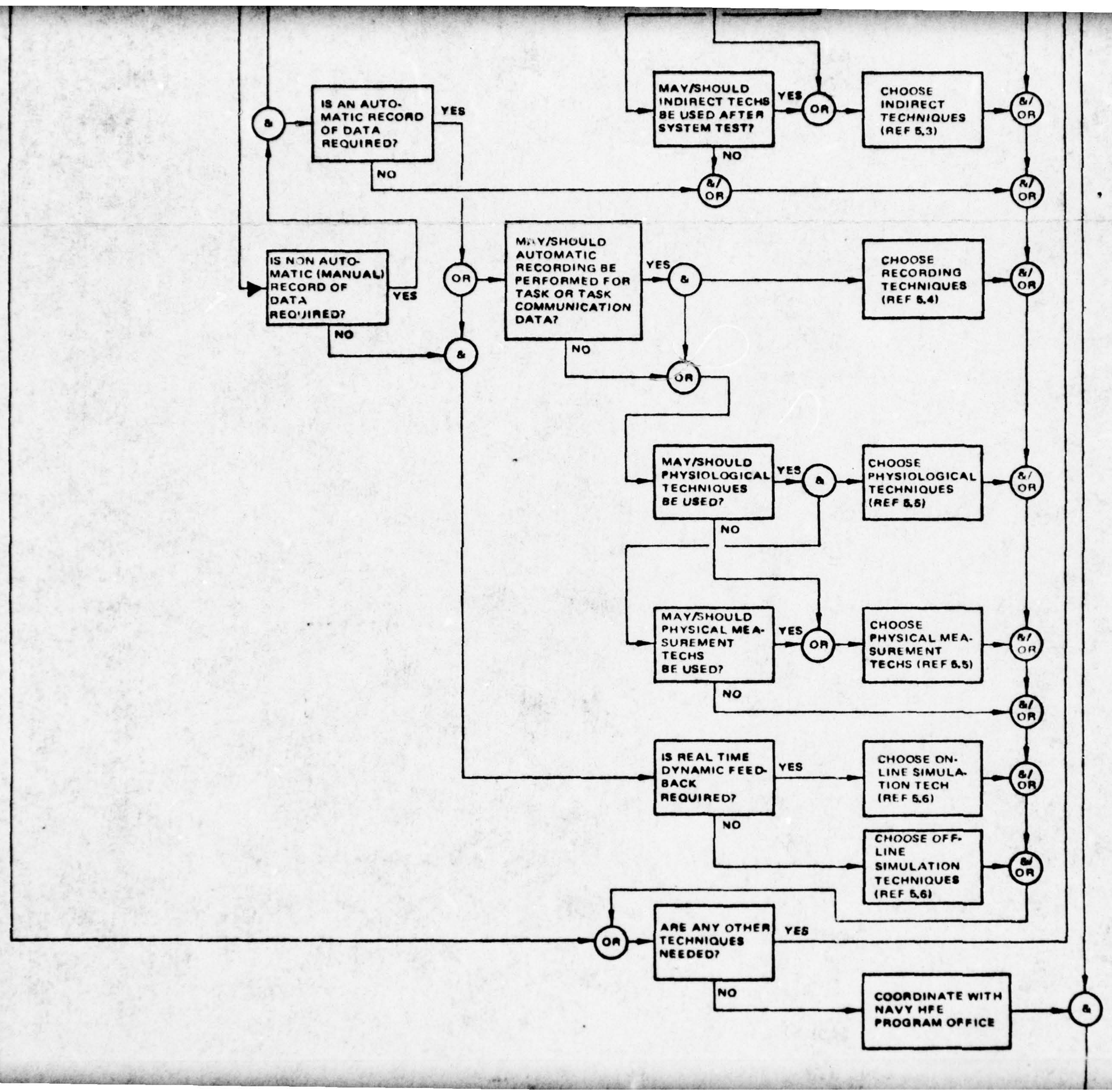

ARE PERSONNEL READILY AVAILABLE TO PERFORM HFE T&E EFFORT?
YES
NO
OR
IS T&E TECHNIQUE TRAINING REQ'D?
YES
NO
PERFORM T&E TECH TR'NG
OR
&
&/OR
ARE HFE SUBCONTRACTORS AVAILABLE TO PERFORM HFE T&E EFFORT?
YES
NO
CONTRACT WITH HFE SUBCONTRACTORS
OR
HIRE HFE PERSONNEL
6. SUBCONTRACTORS
&/OR
ARE THERE ANY HFE T&E TASKS THAT SHOULD BE PERFORMED BY SUBCONTRACTORS?
YES
NO
CAN HFE T&E REQUIREMENTS BE INCLUDED IN SUBCONTRACT?
YES
NO
DETERMINE DID'S AND MIL-H-46855 SECTIONS SUBS SHOULD ADHERE TO
PUT HFE REQM'TS INTO SUBCONTRACTOR CONTRACT
OBTAIN NECESSARY DATA INPUTS FROM SUBCONTRACTORS
PERFORM REQ'D HFE T&E (FOR SUBS)
MONITOR SUB-CONTRACTORS PROGRAM PERFORMANCE
OR
OR
COORDINATE WITH NAVY HFE PROGRAM OFFICE
&/OR
7. SOURCE DATA
DETERMINE IF DATA IS AVAILABLE TO INITIATE THE HFE T&E EFFORT
IS GENERAL DOCUMENTATION AVAILABLE DESCRIBING OPER/MAINT PERS. ROLE?
YES
NO
&/OR
USE OPER/ MAINT DATA (REF FLAG)
COORDINATE WITH NAVY HFE PROGRAM OFFICE
REVIEW PREVIOUS HFE T&E DATA (REF FLAG)


4
REVIEW PREVIOUS HFE T&E DATA (REF FLAG)
COORDINATE WITH NAVY HFE PROGRAM OFFICE
DEVELOP APPROPRIATE ANALYSIS & EVALUATION CRITERIA
IS HFE DATA AVAILABLE FROM SOME SIMILAR PROGRAM?
CAN THIS DATA BE USED ON THIS NEW PROGRAM?
YES
NO
OR
&
MAKE SPECIAL NOTE OF CONSTRAINTS
ARE THERE PARTICULAR OPERATOR CONSTRAINTS IMPLIED IN THIS DATA?
DETERMINE HFE T&E TEST SUCCESS CRITERIA
DOCUMENT SUCCESS CRITERIA
&/OR
SHOULD SYSTEMS/HFE ANALYSIS BE PERFORMED?
CAN SYSTEMS/HFE ANALYSIS EFFORT BE PERFORMED BY HFE ORGN.?
IS BUDGET AVAILABLE FOR SYSTEMS/HFE ANALYSIS EFFORT?
NOTIFY NAVY PROGRAM OFFICE
INSURE DATA ARE GENERATED BY SYSTEMS GROUP
B. TECHNIQUES AVAILABILITY
DETERMINE WHAT ANALYSIS TECHNIQUES SHOULD BE USED? (REF. SECTION 5.0)
ARE ALL HFE T&E ANALYSIS TECHNIQUES SPECIFIED BY DID'S?
ARE ALL T&E TECHS AVAILABLE TO PERFORM THE HFE EFFORT?



(REF. SECTION 5.0)
TECHNIQUES SPECIFIED BY DID'S?
NO
OR
ARE ALL T&E TECHS AVAILABLE TO PERFORM THE HFE EFFORT?
YES
NO
&
IS THERE A NEED TO DEVELOP NEW UNIQUES HFE T&E TECH'S
YES
NO
COORDIANTE WITH NAVY HFE PROGRAM OFFICE
ARE SOME/ALL COMPUTER TECHS AVAILABLE?
SUBCONTRACT OR OTHERWISE INITIATE NECESSARY COMPUTER PROGRAMS
ARE SOME/ALL OF THESE NEW TECH'S COMPUTER AIDED?
ARE SOME/ALL OF THESE NEW TECH'S MANUAL?
DEVELOP COMPUTER TECH'S
DEVELOP NEW MANUAL TECHNIQUES
9. TECHNIQUES SELECTION
CHOOSE EXISTING SUITABLE HFE T&E TECHNIQUES
MAY/SHOULD TECHNIQUES BE USED DIRECTLY DURING TEST?
DETERMINE DIRECT OBSERVATION TECHNIQUES
MAY/SHOULD DIRECT OBSERVATION BE CONTINUOUS?
CHOOSE TECHNIQUES
CHOOSE DIRECT CONTINUOUS OBSERVATION TECH (REF 5.1)
MAY/SHOULD DIRECT OBSERVATION BE SAMPLED?
CHOOSE DIRECT SAMPLED OBSERVATION TECH & CRITERIA (REF 5.1)
&/OR
CHOOSE SYSTEM MEASUREMENT TECHS (REF 5.2)
MAY/SHOULD INDIRECT TECHS BE USED AFTER SYSTEM TEST?
CHOOSE INDIRECT TECHNIQUES (REF 5.3)
IS AN AUTOMATIC RECORD OF DATA

6



IS AN AUTO-MATIC RECORD OF DATA REQUIRED?
YES
NO
IS NON AUTO-MATIC (MANUAL) RECORD OF DATA REQUIRED?
YES
NO
MAY/SHOULD AUTOMATIC RECORDING BE PERFORMED FOR TASK OR TASK COMMUNICATION DATA?
YES
NO
MAY/SHOULD INDIRECT TECHS BE USED AFTER SYSTEM TEST?
YES
NO
CHOOSE INDIRECT TECHNIQUES (REF 5.3)
CHOOSE RECORDING TECHNIQUES (REF 5.4)
MAY/SHOULD PHYSIOLOGICAL TECHNIQUES BE USED?
YES
NO
CHOOSE PHYSIOLOGICAL TECHNIQUES (REF 5.5)
MAY/SHOULD PHYSICAL MEA-SUREMENT TECHS BE USED?
YES
NO
CHOOSE PHYSICAL MEA-SUREMENT TECHS (REF 5.5)
IS REAL TIME DYNAMIC FEED-BACK REQUIRED?
YES
NO
CHOOSE ON-LINE SIMULA-TION TECH (REF 5.6)
CHOOSE OFF-LINE SIMULATION TECHNIQUES (REF 5.6)
ARE ANY OTHER TECHNIQUES NEEDED?
YES
NO
COORDINATE WITH NAVY HFE PROGRAM OFFICE
&
OR
&/OR

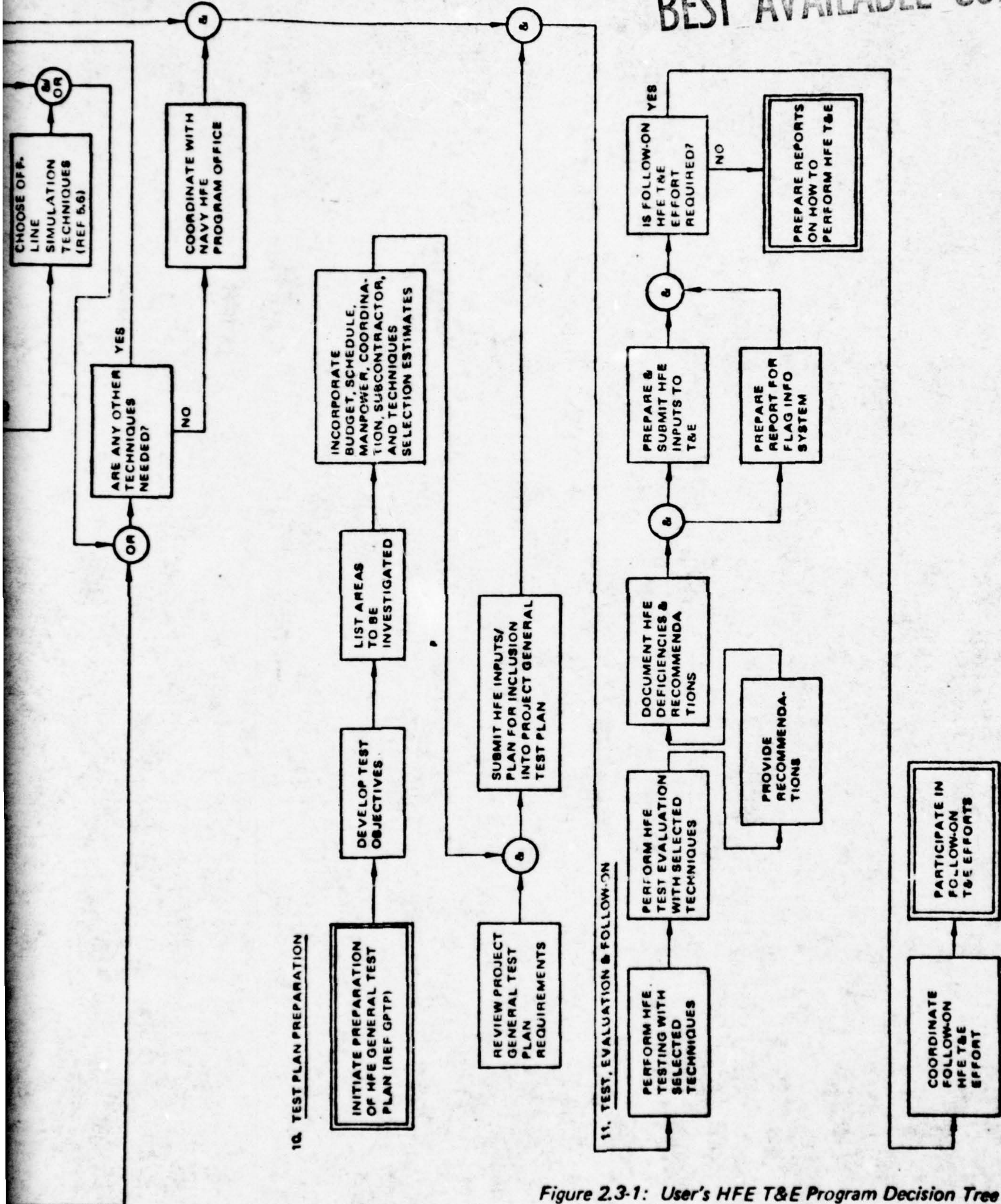


Figure 2.3-1: User's HFE T&E Program Decision Tree (For T&E Portion of MIL-H-46855)

The pertinent decisions and possible actions have been placed on the flow chart diagram in blocks adjacent to other associated or related decision and action blocks. Arrows are provided between the blocks to indicate the direction of sequence of task action. The placement of several blocks on a single page with connecting arrows allows the HF engineer to quickly see relationships between each of the tasks that he must accomplish. A narrative description of these same HFE T&E tasks and task relationships would undoubtedly be hopelessly complex.

2.4 Basic Considerations

There are several important considerations pertaining to the HFE T&E effort which are in addition to the appropriate sections of MIL-H-46855, the program manager's guidelines, the company or organization policy, and the other constraints indicated in Sections 2.1, 2.2, and 2.3. These considerations consist of the type of data required to start an HFE T&E effort, the timing as to when to perform the T&E, the level of T&E detail required, the use of the HFE evaluator's judgment, and the type of specific results normally expected from the HFE T&E effort. Section 5.0, "T&E Techniques", deals with these basic considerations in relation to specific HFE T&E techniques, but this section pertains to these basic considerations in relation to the overall HFE T&E effort.

2.4.1 Data Inputs

These consist of criteria or human performance requirements that are to be determined or verified by T&E. They may be system or mission requirements established early in the program. They may be military specifications and standards criteria. Operator/maintainer requirements (and assumptions) developed out of the MIL-H-46855 analysis effort should be available for evaluation. Ideally, these data are available from a program data retrieval system (e.g., FLAG). They may be available from another technology than HFE. In any case, T&E should be conducted against set test criteria (success criteria) and if the data does not exist, it must be generated. Also, the TEMP (Reference 1) and HFTEMAN (Reference Section 5.1.7) should be used as inputs.

During early program phases, all of these data are tested against drawings and static mockups. As the program progresses and T&E becomes more formal, more sophisticated mockups and prototype hardware are used.

2.4.2 Timing

Without the proper scheduling of the HFE T&E effort, it can turn out to be of little use to the system design. It is not sufficient just to perform HFE T&E. It is equally important to demonstrate that the results of the effort will be completed or partially completed at a point in the schedule when it can properly impact the system design. All too often, HFE T&E is performed as an after-the-fact documentation exercise or just a workaround procedure that appears in a technical publication. The later the design is tested, the less chance there is to modify the crew station or other man/machine interface. Late findings of serious crew system problems can be extremely expensive, both in accidents and system redesign.

Appendix D shows the stage or phase of a program for which a particular technique is best suited.

2.4.3 Level of Detail

The level of T&E detail that must be performed is significant to the HFE manpower effort. If the wrong emphasis is given to the amount of detailed data gathering, HFE T&E may be wasted by either obtaining data that has no use or by failing to obtain sufficiently detailed data to be useful. It is the job of the HFE observer or manager to decide what level of T&E will lead to worthwhile data or useful design criteria. For example, new system designs or programs often contain requirements that are identical to previously designed and tested systems. There is probably no point in repeating a detailed HFE T&E of all the system functions and operator tasks that have already been evaluated. It is simply not cost effective, especially when new program schedules and manpower budgets generally are extremely limited. The old system test and evaluation results should provide all the data that would be needed for that portion of the new system design criteria.

The effort that should be expended during the new program is on the new and potentially critical functions and tasks. These are the kinds of tasks that appear to be marginal in terms of operator reliability, time performance, or safety hazards. The level of test and evaluation detail attempted for such tasks should be as far down as possible to the subtask element (indicator monitoring/button pushing) based on program timing/scheduling.

On new system designs it may be necessary to analyze data down to as much detail as a tenth of a second. If the HFE program has been properly managed, all system potentially critical tasks will have been previously indicated for special HFE T&E considerations. In any case, the need to gather human performance related T&E field data beyond a tenth of a second is extremely doubtful. In a similar manner, the HFE should maintain adherence to the rules for significant figures and common sense when gathering data on light levels, sound levels, reach envelope measurements, etc.

2.4.4 Evaluator's Judgment

The use of an experienced HFE observer/evaluator's judgment is an extremely important basic consideration. The evaluator's judgment or "gut feel" of a test situation might be one of the most important HFE T&E techniques if it could be described more analytically as a step by step procedure to follow. However, it is not that sort of thing. This consideration is simply the summary of the evaluator's significant impressions as a result of observing the system test. It would be convenient to have all test data gathered in an easily useable quantifiable form. But there is no way to measure all test performance parameters. The written (or spoken) impressions of the experienced HFE evaluators generally prove to be extremely valuable and cost effective.

Examples of test information that are best described based on an experienced evaluator's judgment are: a) test precision (or lack of same), b) workspace layout adequacy, c) test participant skill, and d) test participant training. It is difficult to measure these qualities in any other way during a test. The results of the HFE evaluator's observation and judgment should be documented as a part of the system test report. This would include the evaluator's "judgment" as to a test problem solution.

2.4.5 Applications

The end products of the HFE T&E effort are to verify system design, discover system inadequacies, provide recommendations for design or other system changes, and provide information for a data bank of human performance and crew systems design related data to be used on later programs. These outputs may be left in the form of the T&E technique worksheets. More probably, the outputs should be condensed and otherwise modified to make them more easily understood by the program design personnel and others who have use of them. (See Reference 11 for GPTP guide for standardized foramts). Table 2.4-1 shows the applications for data developed from using the various listed T&E techniques.

It may be of use to HFE's to prioritize T&E results in some manner in order to show that there are certain absolutely essential system modifications required. The risk of not doing this is to have insignificant results acted upon and critical data ignored. All findings must be well documented and files must be maintained. By themselves, verbal inputs as to T&E results have virtually no chance of acceptance.

Table 2.4-1, HFE T&E Techniques Data Applications

SPECIFIC HFE T&E TECHNIQUES/TOOLS	APPLICATIONS / PAGE REFERENCE	CONCEPT FORMULATION IDEAS	DETAILED DESIGN REQUIREMENTS	PERSONNEL REQUIREMENTS INFO	OPERATIONAL PROCEDURES DEVELOPMENT	TRAINING SYSTEM DEVELOPMENT	MAINTENANCE SYSTEM DEVELOPMENT	SYSTEM OPERATIONAL EVALUATION	ADDITIONAL HUMAN FACTORS ANALYSIS	HFE DATA STORE INFO (FLAG)
MANUAL DIRECT:										
CONTINUOUS OBSERVATION	43	●	●	●	●	●	●	●	●	●
SAMPLED OBSERVATION	45	●	●	●	●	●	●	●	●	●
DESIGN CRITERIA CHECKLIST	46		●				●	●		●
SPEC COMP SUMMARY SHEET	49		●				●	●		●
T.O. FUNCT EVALUATION	52				●		●	●	●	●
HPR TESTING	56						●	●	●	●
HFTEMAN	58		●				●	●		●
G-2/G-5 ANTHROPOMETERS	60	●	●					●		●
TERRAIN VISIBILITY DEF	61	●	●					●		●
ENV & PERF MEAS. EQUIP.	65	●	●					●		●
MANUAL SYS MEASUREM'TS:										
SYSTEM RECORDS REVIEW	67			●	●	●	●	●	●	●
HUMAN INITIATED FAILURES	69		●	●	●		●	●	●	●
TEST PART. HISTORY RECORD	70			●		●		●	●	●
MANUAL INDIRECT:										
INTERVIEWS	73	●	●	●	●	●	●	●	●	●
QUESTIONNAIRES	77	●	●	●	●	●	●	●	●	●
FUNCT DESC INV(FDI)	82			●		●		●	●	●
PAARS	84			●	●		●	●	●	●
COOPER-HARPER	85		●					●		●
PROBLEM INCIDENT REP	89		●	●	●		●	●	●	●
AUTOMATIC RECORDING:										
MOTION PICTURES	92	●	●	●	●	●	●	●	●	
SOUND TAPES	94	●	●	●	●	●	●	●	●	
VIDEO TAPES	95	●	●	●	●	●	●	●	●	
PHOTOGRAPHY	97	●	●	●	●	●	●	●		
EVENT RECORDING	99	●					●	●	●	●
OPREDS	103			●	●	●		●	●	●
SECONDARY TASK MON.	109	●		●				●	●	●
AUTOMATIC PHYSIOLOGICAL:										
PHYSIOLOGICAL INSTRUMENTATION	110	●						●		●
PHYSICAL MEASUREMENT	113	●		●				●	●	●
SIMULATION:										
CGE	116	●	●							●
CAR	119	●	●							●
CAPE	121	●	●							●
FOVEA	125	●	●					●		●
ONLINE INTERACTIVE	126	●		●	●	●			●	●

3.0 TYPES OF HFE TEST AND EVALUATION

As indicated in the introductory section of this guide, there are different types of T&E. The definitions provided there are precise since they are based on the Reference 1 instruction. There are additional detailed definitions provided in Reference 1 that are included in this section of the guide. There are also included herein the less formal definitions which are based on either system program schedules or funding sources.

3.1 Informal vs. Formal T&E

In attempting to develop an integrated HFE T&E technology, one needs to recognize that different types of test and evaluation are involved in systems development (both in DT&E and OT&E): One, called HFE "t&e" (lower case) is predominant in design concept feasibility efforts and in selection from design configuration alternatives. Design concept feasibility efforts are exploratory in nature. They are extremely dependent upon paper analysis. The observation, experimentation and testing activities in this category are oriented to the goal of developing new knowledge. The selection of design configuration alternatives is a resolution process in which trade studies are performed and evaluated. The other type of test and evaluation, labeled HFE "T&E", is predominant in system performance verification. System performance verification is performed with mockups and prototype hardware. The objective which characterizes this category is one of determining whether a man-machine system, as designed, meets its performance requirements. Systems performance verification is a much more formal test and evaluation than the lower case "t&e". It is this latter type of T&E (capital letters) which is covered by this guide since the applicable paragraph in MIL-H-46855 carries the heading "Human Engineering <u>in</u> Test and Evaluation". At the same time, HFE "t&e" may be called for (both exploratory and resolution) when system program Engineering Change Proposals (ECP's) are required. The relationship between these differential aspects is illustrated in Figure 3.1-1.

3.2 OPNAVINST 3960.10 Definition

OPNAVINST 3960.10 (Reference 1) makes a formal distinction between three types or phases of T&E. These are Development Test and Evaluation (DT&E),

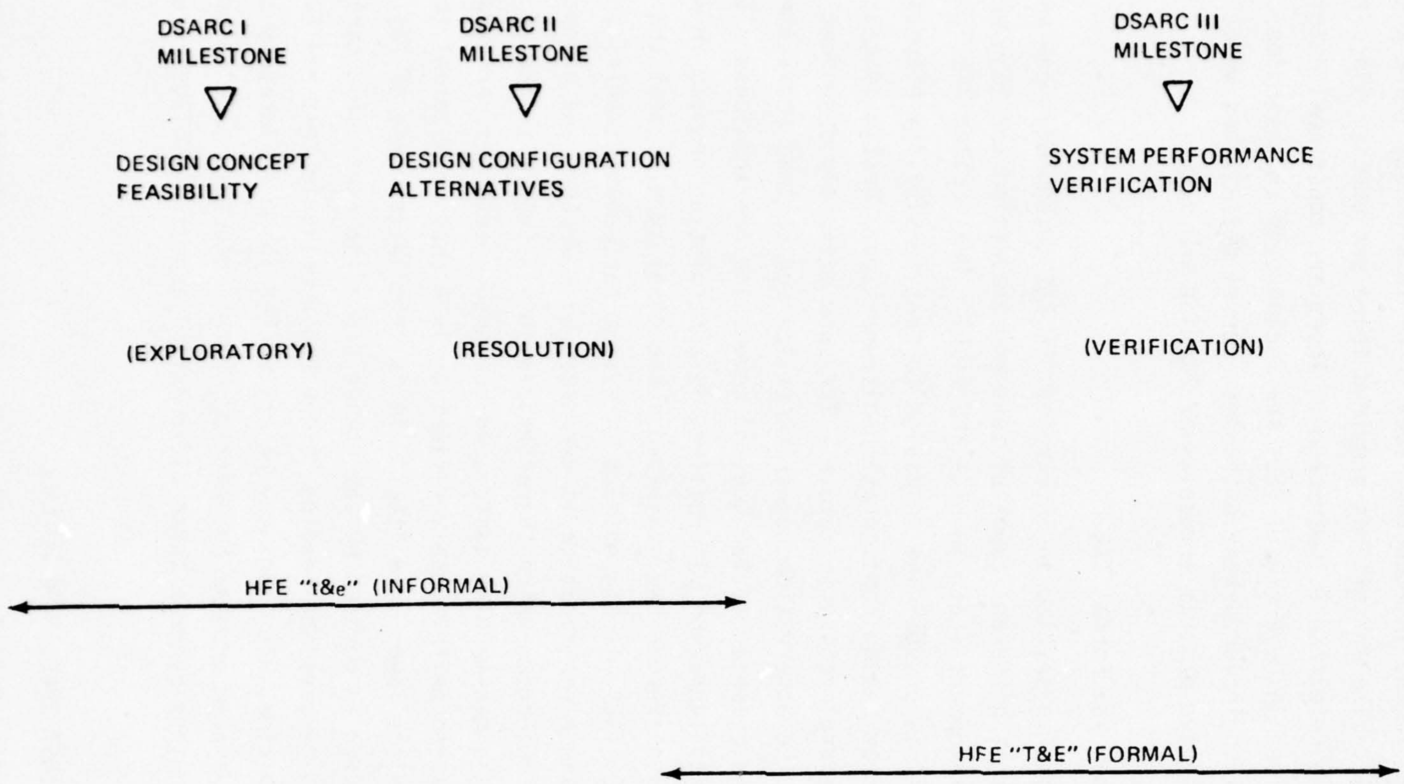


Figure 3.1-1: Informal vs. Formal Aspects of HFE T&E

Operational Test and Evaluation (OT&E), and Production Acceptance Test and Evaluation (PAT&E). These types of T&E are shown in relation to each other, to their subphase elements, and to the program phases and milestones in Figure 3.2-1. It is interesting to compare this figure with the Figure 3.1-1 definition of T&E by phases.

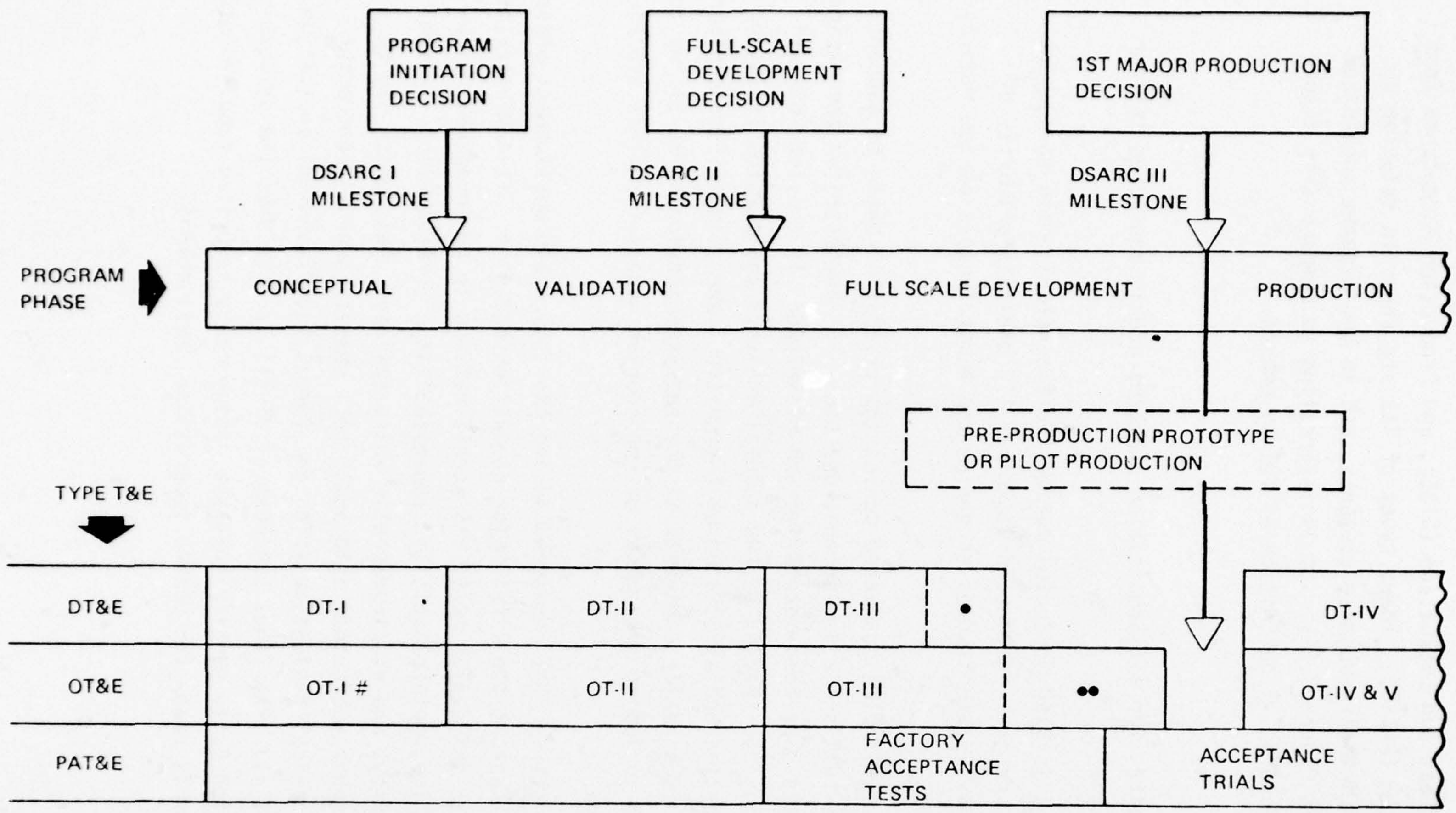
3.2.1 DT&E

DT&E is required for all acquisition programs and is conducted in four major phases:

a) DT-I is DT&E conducted during the conceptual phase to support the program initiation decision. It consists primarily of analysis and studies to derive the human factors/system requirements.

b) DT-II is DT&E conducted during the validation phase to support the full scale development decision. It demonstrates the design risks have been identified and minimized. It consists of verifying the results of the special analysis and studies including modeling and simulation on the critical areas identified earlier. It is normally conducted at the subsystem/component level, up to and including employment of engineering models for final evaluation.

c) DT-III is DT&E conducted during the full scale development phase to support the first major production decision. It demonstrates that the design meets its specifications in performance, reliability, maintainability, supportability, survivability, system safety, and electromagnetic vulnerability. This phase may be further subdivided into additional phases, such as Contractor Technical Evaluation (CTE) and formal Navy Technical Evaluation (NTEs). The final subphase of DT-III is TECHEVAL, the purpose of which is to certify that the design meets specified requirements and is ready for OPEVAL (operational evaluation).



• TECHEVAL
•• OPEVAL
= NOT REQUIRED FOR MOST ACQUISITION PROGRAMS

SOURCE: OPNAVINST 3960.10
22 OCT. 1975

Figure 3.2-1: Test & Evaluation Phases

d) DT-IV is DT&E conducted after the first major production decision to verify that product improvements, or correction of design deficiencies discovered during OPEVAL, FOT&E (follow-on test and evaluation), or fleet employment, are effective.

3.2.2 OT&E

OT&E is required for all acquisition programs except for those programs designated by Chief of Navy Material. OT&E is subdivided into two major categories: initial OT&E (IOT&E), which is all OT&E accomplished prior to the first major production decision; and follow-on OT&E (FOT&E), which is all OT&E after the first major production decision. OT&E is further divided into five major phases (3 IOT&E, and 2 FOT&E):

a) OT-I is any IOT&E that may be conducted during the conceptual phase to support the program initiation decision. Most acquisition programs do not require OT-I. However, when an OT-I is conducted, existing systems or modifications thereto will normally be used to help estimate the military utility of the proposed new system.

b) OT-II is IOT&E conducted during the validation phase to support the full-scale development decision. It provides an early estimate of projected operational effectiveness and operational suitability of the system; initiates tactics development; estimates program progress, and identifies operational issues for OT-III.

c) OT-III is IOT&E conducted during the full-scale development phase to support the first major production decision. OPEVAL (Operational evaluation) is the final subphase of the OT-III. It consists of a demonstration of achievement of program objectives for operational effectiveness and operational suitability, and continuing tactics development. OPEVAL normally uses pilot production hardware, and begins about one month after completion of TECHEVAL (technical evaluation) testing.

d) OT-IV is FOT&E conducted after the first major production decision, but before production systems are available for testing. Normally, OT-IV is conducted with the same pre-production prototype or pilot production systems used in OPEVAL. OT-IV consists of testing of fixes to be incorporated in production systems, completion of any deferred or incomplete IOT&E, and continuing tactics development.

e) OT-V is FOT&E conducted on production systems as soon as they are available. OT-V provides for a demonstration of the achievement of program objectives for production system operational effectiveness and operational suitability. In addition, OT-V includes OT&E of the system in new environments, or in new applications, or against new threats.

3.2.3 PAT&E

As previously indicated, PAT&E is testing conducted on production items to demonstrate that systems meet contract requirements and specifications. There are no subphases to PAT&E.

3.3 General Definitions

Further definition of HFE T&E may be made from the standpoint of the money source to pay for the T&E job, e.g., if design engineering money pays for an evaluation of some item of hardware, then the evaluation process is considered "design". In a similar manner, the program schedule helps define the terms, e.g., a paper analysis of a system concept may be considered as an on-paper "evaluation". However, since it may occur early in the program during the concept definition phase, it will most probably be considered "analysis" at that time period.

The total spectrum of how to categorize and differentiate among the divergent objectives, criteria and applications of test and evaluation need to have an agreed upon definition between customer and contractor and between customer agencies before significant HFE T&E program work may occur. A good starting

point for establishing a baseline for this would be Meister's Human Factors: Theory and Practice (Reference 19), and the somewhat earlier Meister & Rabideau Human Factors Evaluation in System Development (Reference 14).

[19] Meister, D., Human Factors: Theory and Practice, Wiley, New York, 1971.

4.0 T&E METHODS

Numerous HFE T&E techniques have been developed in response to different needs or characteristics that have been required of each. It is the intent of this section of the guide to describe both the basic HFE T&E methods, or general techniques, and the characteristics that are used to evaluate them. The methods are described and evaluated in general in relation to the different qualities or characteristics that each typifies. Also, the use of mockups, models, and prototype hardware are discussed briefly in this section.

4.1 Technique Evaluation Characteristics

The choice of the most efficient technique for performing an HFE T&E is a critical step in the total evaluation process. The general technique or method chosen will influence the entire conduct of HFE T&E. Several technique characteristics have been selected for use in evaluation of the different T&E methods/techniques. The techniques may be compared to each other by use of narrative comments for each evaluation characteristic or by use of the Appendix D technique evaluation worksheets. The evaluation factors used to choose the techniques are described in the following sections.

4.1.1 Program Use

One of the several ways a technique might be selected is on the basis of what previous systems/programs have successfully used that method. The HFE evaluator may be able to obtain details as to the use of the technique by contacting the HFE personnel who have worked the previous program. Another usage factor is the applicable stage or phase of a program that the technique is best suited for. Some techniques are best used for future programs such as the F-18, or existing programs such as the P-3. For example, some of the off-line cockpit geometry computer programs should not be used in evaluating an existing P-3 cockpit. If the evaluation is still needed, it is easier to examine the actual aircraft rather than simulate it.

4.1.2 Inherent Features

Rather than include all the inherent characteristics of a technique in an applicable/not applicable categorization, these characteristics are best considered as a separate list for each technique of all of the advantages and disadvantages of that particular technique. The inherent validity or repeatability of the technique should be considered along with the advantages and disadvantages. The implications of not using the technique should also be included. For example, this could be a list of other techniques which might yield similar data, or the fact that the technique is the only one available to provide a certain type of data.

4.1.3 Best Use

These characteristics cover several aspects of technique comparison. Certain techniques may be considered as best for gathering either subjective or objective data. In most cases, these amount to qualitative or quantitative data respectively. However, some subjective data is quantitative (numerical ratings) and some objective data is purely qualitative (go/no go conditions).

Some techniques are best suited for pure testing as opposed to pure evaluation. For example, the end product of some techniques is simply readouts of alphanumeric data. Other techniques are needed to analyze, evaluate, or draw conclusions from the raw data originally available.

Many techniques are best used for only a portion of the total system being evaluated. They may be useful for examining the HFE aspects of a component, but much less useful for a subsystem evaluation, and not of any value for a complete system. In a similar manner, some techniques are best used for performing T&E on only a single task performed by one test participant. Other techniques work well on several tasks being performed nearly simultaneously by several test participants.

4.1.4 Relative Performance

These characteristics pertain to the ease of using one technique versus

another in terms of time to perform, complexity, personnel required, and cost. The relative time required to perform a technique for a given test may be described as short, medium, or long. The time factor may be significant depending on test schedules. The complexity characteristic is important if the skills of the HFE test observer personnel is limited by experience. The number of personnel is also significant if the HFE organization is limited and/or other important tests must be observed simultaneously. The cost is, of course, one of the most important of all the test evaluation characteristics.

4.1.5 Program Interface Requirements

These characteristics include the input and outputs to/from the techniques and the coordination required in order to use the technique. Prior to choosing a technique, it is important to know if the proper ingredients are available to initiate the technique. It is also important to know if the outputs will be what is desired or in the required format (Reference 10). Special test coordination as to other organizations or support that is necessary to perform the test must also be considered in choosing HFE T&E techniques.

The need for a particular T&E technique to be performed on a test "interference basis" is extremely important. An interference basis test is defined as one which allows very little other testing (HFE or any other) to be conducted simultaneously. The conduct of formal T&E is a relatively expensive operation. It is therefore desirable to have as much HFE T&E as possible be conducted during the performance of other testing on a noninterference basis. In many instances, more realism may be obtained if the HFE testing is performed along with the conduct of other major system tests.

The advantage of tests conducted for HFE alone are in the ability to more easily control test variables and to study a wider range of test conditions. However, such testing for HFE alone is more expensive. One alternative to noninterference testing would be in the performance of static or "power-off"

testing which could be performed by HFE during the periods of time that the test equipment or mockups are not being used by any other test organizations. The use of the design criteria checklist is an example of such a test technique that could be used in this manner.

4.2 General Technique Categories

The various HFE T&E techniques are categorized for the purpose of reference and comparison with the previously indicated technique evaluation characteristics. Examination of the various technique types leads to the realization that two major categories are automatic and manual. The automatic techniques rely primarily on test instrumentation or computer simulations. The manual techniques rely to a large extent on the observer as the data collection device. Figure 4.2-1 shows each of the T&E methodologies in relation to their major categorizations.

4.2.1 Manual Techniques

A further distinction in the manual category is that of direct versus indirect observation. System measurement is considered a third category of manual technique; although it could also be classified as a form of indirect observation. Direct manual techniques may be further categorized as being continuous or sampled. System measurement techniques are where the test evaluator gathers HFE T&E data through a review of test logs, maintenance records, or debriefing records to obtain the necessary HFE T&E data. Indirect techniques include interviews and questionnaires. The technique descriptions in Section 5.0 provide considerably more detail in the way of individual technique comparisons.

4.2.2 Automatic Techniques

Automatic techniques are categorized as to those that are primarily measurement devices of external data and those that both measure and create new data based on specified inputs. This later category consists of the computer program techniques or computer simulations. These may be further divided into on-line interactive techniques and off-line (e.g., batch mode) techniques.

The measurement devices include all of the recording techniques/tools such as video tapes, sound tapes, event recorders, and photography. Measurement

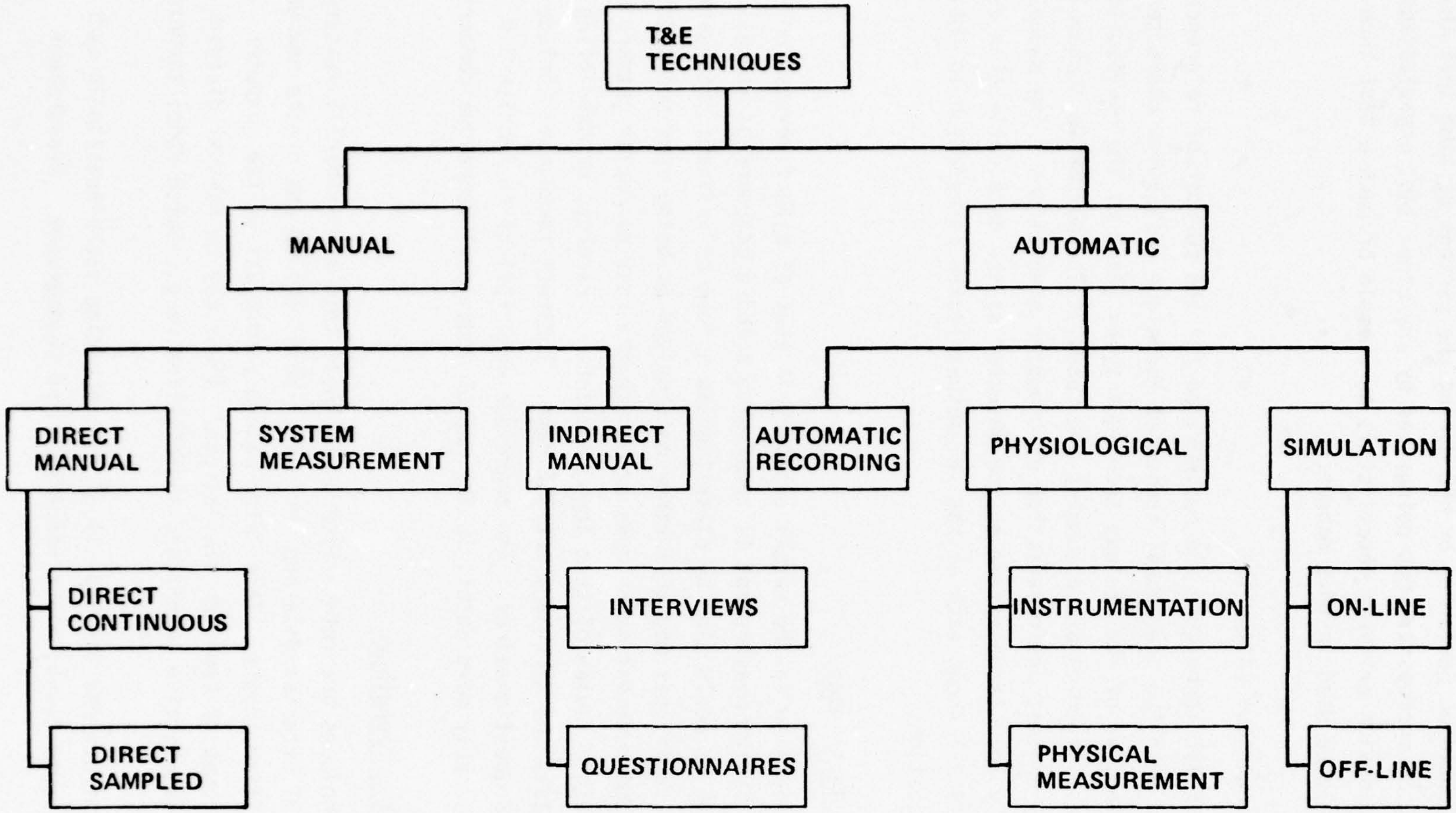


Figure 4.2-1: Categories of T&E Techniques

devices also include physiological instrumentation of parameters such as heart rate and EEG. Also included under measurement devices are the physical anthropological techniques/tools such as the tape measure and goniometer.

4.3 Inherent Technique/Characteristic Relationships

The particular relationships between techniques and evaluation characteristics may be found in Section 5.0 and in Appendix D. There are, however, some general relationships that may be stated. One general relationship is somewhat similar to the relationship noted between man (manual) and machines (automatic) in the notable Fitts list (Reference 3).

Manual techniques tend to be more subjective and qualitative than automatic techniques. Their cost tends to be lower than automatic techniques. Automatic techniques are better used for objective and quantitative data. The validity or reliability of automatic techniques tends to be higher than manual techniques. This is because manual techniques are often based on the opinion of the test participant or observer. Automatic techniques are based on actual measured or precisely calculated data. Automatic techniques tend to be more costly and more complex than manual techniques. Automatic techniques require more time to initiate but once set up, they are more efficient than manual techniques. Simulations are best used early in a program.

Another general relationship between techniques is the inverse relationship between their fidelity (or accuracy) and their ease of use. The end product of any T&E effort is to make valid judgments in regard to the real world situation. Some techniques are inherently more precise than others in terms of their fidelity to the proposed actual operating system situation. Unfortunately, the reason for their fidelity is largely due to the effort required by the use of the technique. This inverse relationship between technique accuracy and ease of use is illustrated in Figure 4.3-1. The real world situation is represented at the left of the figure. The most accuracy would be obtained by always measuring the real world situation. However, as always, the process of making observations or measurements tends to distort the test results and a degree of test fidelity is lost.

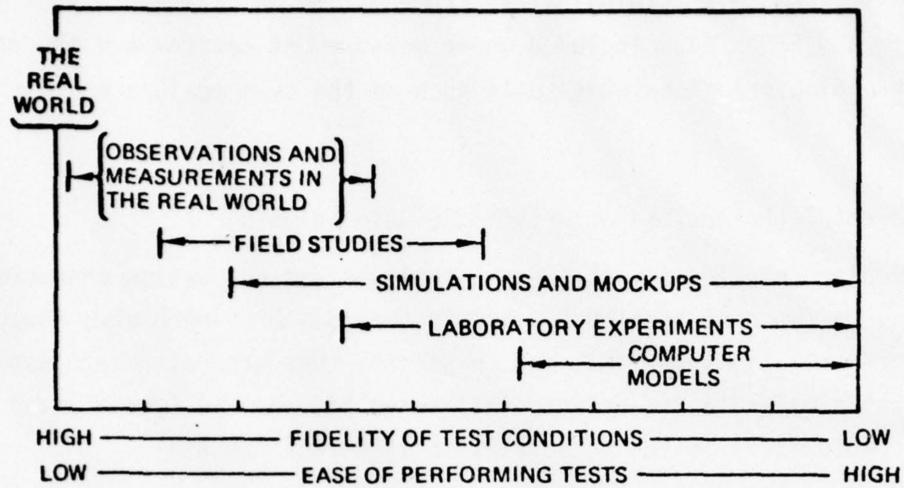


Figure 4.3-1, Technique Fidelity Vs. Ease of Use

Field studies have less fidelity than real world observations because such studies are set up as artificial situations. Simulations with the use of mockups cover a wide range on the fidelity scale. Laboratory experiments also have a wide range of fidelity variability. Some laboratory experiments may be quite realistic while others may be highly abstract. Computer or mathematical models are the easiest to develop, manipulate, and use, but they are the least accurate in their representation of real world situations. Considerable advancement is now being made in the area of developing computer models to simulate more accurately real world situations.

4.4 Drawings, Mockups and Prototypes

There are a number of different tools or media that engineers, in general, and HF engineers, in particular, work with throughout the life of a program. These range from engineering sketches during the exploratory or concept formulation phase of a program to the prototype hardware which would result from a full scale development effort. The techniques that the HFE observer/evaluator uses depend to some extent upon the media or engineering tools available.

The first tools with which the HFE has to work during the "t&e", or exploratory, phase of the program are engineering sketches. These sketches may be well crafted engineering drawings but are referred to as sketches only because of their intended lack of contractor of customer sign-off approval. Interface control drawings are another type of drawing that should require HFE review. As the name implies, these drawings are used to describe and to eventually control proposed interfaces between components, subsystems, or different contractor's equipment items. Most of these types of drawings may be used to perform a rough HFE evaluation, particularly by use of the design criteria checklist. Software and equipment item specifications are prepared to do document required system component performance and design criteria. To a limited extent, these may be used to verify compliance with contractual specifications. HFE T&E computer simulation techniques may be used to test system design concepts as indicated in the drawings and equipment item specifications.

As the system design progresses, full-scale mockups should be constructed to evaluate workspace and accessibility provisions. Wiring, cabling, piping, and ducting may be designed and evaluated much more easily with mockups. It is difficult to visualize three-dimensional problems from scaled down, two-dimensional drawings. The mockups should be made initially with the easiest to use and cheapest material possible. Various thickness plastic foam core filled cardboard sheets may be used quite easily with a hot glue gun and a sharp matte knife to build consoles, racks, and even complete cockpits. Console panel layout drawings may be simply glued to the foam core cardboard to simulate the appropriately located displays and controls. Test participants or evaluators may simulate the observation of displays or actuation of controls by simply touching the drawing and performing the appropriate hand (foot) motion. As the system design progresses and mockup tolerances become more critical, plywood material should be used. Plywood is both more rigid and durable, although considerably more costly in terms of construction costs. The plywood mockups may be converted from a static representation of the system to a dynamic or hot mockup. These mockups are also referred to as functional mockups. The console panel drawings which were glued to the plywood may be replaced by the actual displays and controls. It is cheaper to develop a hot mockup, which includes the proposed

electrical wiring, than it is to build a prototype with numerous design errors. A functional mockup makes it possible to study the performance of personnel in simulated operational situations. The HF engineer can thereby evaluate operating characteristics of equipment in terms of human performance. More realistic lighting and sound measurements may be taken. Procedures may be verified. Test participants may be observed and interviewed with a much greater degree of confidence as to the validity of their responses. In addition to all of the above, mockups along with photographs and movies provide a means of design documentation to show the evolution of the system configuration.

The last major engineering tool short of the production hardware is the prototype. This is the first item of hardware produced. Whereas it is the most valid representation of the proposed system end item, it does not necessarily comply with all system requirements. Depending on the objective of the system design, the prototype hardware may be the first opportunity to evaluate the design in a mobile state. With the exception of the computer simulation techniques, virtually all of the HFE T&E techniques may be used for prototype hardware man/machine evaluation.

5.0 T&E TECHNIQUES

This section contains details as to the description, use or validity, references, and in some cases, samples of 33 significant HFE T&E techniques. They are listed according to the categorization presented in Section 4.2.

5.1 Direct Manual

5.1.1 Direct Continuous Observation

Description: This technique is simply the process of taking a relatively continuous record of the task or work activity or some aspect of the test performance. The operation may consist of an observer keeping a running log or description of the test activity as he understands it. The data may be recorded by hand on a clip board, or some of the more sophisticated techniques/tools (Section 5.4.5) may be used for recording events and times. Automatic recording techniques such as photographs, movies, and sound and video tapes (Section 5.4.3) may also be used along with direct observation.

The detail of the observed data is in accordance with the basic considerations indicated in Section 2.4. The observer should be skilled at being able to discriminate what significant events occur during the test. These events should be summarized and interpreted for later action. The observer must be familiar with the anticipated man/machine system performance. He will observe test participants while they are using either mockups or actual hardware. The observer should be particularly interested in obtaining data on operator task times and errors. Data as to the observer's estimates of participants' training, skills and quantities should also be recorded. Life support, safety and hardware design criteria compliance may also be observed.

The use of the direct observation technique involves the use of mockups or hardware. Therefore, the most appropriate time

to use this technique would be any time after the system concept has evolved sufficiently to produce three dimensional mockups.

Use/Validity: Observation is one of the most common methods of evaluating personnel and system performance. It is used to some extent in some form in every test and evaluation. Despite the increasing use of automatic recording devices the requirement for direct observation will never be completely eliminated.

Observation may be used on any portion of a total system, a subsystem, or on system components. It is useful for T&E of single task performance or the simultaneous operation of several tasks by several test participants. It is simple to perform in comparison with other T&E techniques.

The major advantages of the direct continuous observation technique are two-fold: the observer is forced, by way of his observation, to learn about the system operation; the observer gets to know the test participants, which may be helpful with possible later interviews.

During the conduct of the test it is possible for the observer to do more than simply record test occurrences. The observer may evaluate test data for possible recommendations or test action items. If direct continuous observation is not used, there is a risk of missing an overall impression of the test as well as random test events or details that would otherwise be overlooked.

One of the disadvantages of using this technique is the requirement for specialized observers for each of the different test aspects or categories. It is seldom possible for a single observer to learn a sufficient amount about all system aspects to perform an adequate job of observing all system tests.

The use of continuous observation implies some periods of test observation that are not productive in terms of gathering HFE T&E data.

References: a) Air Force, Test Plan for Category II Testing of System 416M, Prepared by the 416M Test Force, Hanscom AFB, November 1963.

b) Alter, F. H., Ground Electronics System for WS-133B (Minuteman), PSTE Plan, MOP PD0060, Sylvania Electronic Systems, Minuteman Program Office, Waltham, Mass., March 1964.

c) Lathrop, R. C., et al, Evaluation of the HF Aspects of the GAM-77 (Hound Dog), APGC-TN-60-19, AD 236953, HF Office, Air Proving Ground Center, Eglin AFB, April 1960.

d) Martin Company, PSTE Test Cycle Report on Missile SM68-11, CR-63-43, AD 405 382, Denver, Colorado, February 1963.

e) Martin-Marietta, Titan II Category II Observer/Evaluator Handbook: PSTE Operating Procedures: Maintenance, Logistics, etc. for SM-688, Titan II, Denver, Colorado, July 1963.

f) Meister, D., and G. F. Rabideau, 1965. Human Factors Evaluation in System Development. New York: Wiley.

Additional data on this technique as compared with other manual observation techniques may be found in Appendix D.

5.1.2 Direct Sampled Observation

Description: This technique is identical to the previously listed one with the exception of the amount of time spent by the observer observing the test. The particular times chosen to perform test observation should, of course, be those which coincide with the performance of critical tasks. The determination of anticipated critical tasks should be made on the basis of the program's preceding systems analysis effort. Random sampling for T&E data may be performed if possible critical tasks have not been predicted by analysis.

Use/Validity: The only difference in the use or validity of the sampled observation technique as compared to continuous observation is in cost savings and the risk of missing significant T&E data. It stands to reason that if the tests are not observed continuously the test observers may be used to perform other HFE T&E tasks on other tests or in data reduction and evaluation of previously conducted tests. The number of personnel required to perform HFE T&E may be cut by a factor of one half or more. The disadvantage of the sampling technique is in running the risk of missing important operator performance data or other important HFE related data. If critical tasks cannot be predetermined, test sampling should be performed with relative frequency. All basic categories or types of operator/equipment tasks should be observed several times in order to prevent skewed data.

Reference: Meister, D., and Rabideau, G. F., Human Factors Evaluation in System Development. New York: Wiley, 1965.

Additional data on this technique as compared with direct continuous observation and other manual observation techniques may be found in Appendix D.

5.1.3 Design Criteria Checklist

Description: The checklist is a series of equipment and facilities design requirements or criteria taken from human engineering standards, e.g., MIL-STD-1472, handbooks and guides. Often, during the early stages of a program, a checklist is developed by HF engineers for that particular program. Design criteria which would be applicable to the particular program are extracted from the various standards and handbooks and listed in a program unique checklist. The checklist may be divided up into sections or categories of design criteria corresponding to major equipment or facilities characteristics. These categories might be visual displays, audio displays, controls,

etc. The checklists generally have a space to the right of each listed item of design criteria. This space is divided into three columns: compliance, non-compliance, and not applicable. The HFE evaluator reads the item of criteria, observes the item of hardware (or mockup or drawing), and checks the appropriate space for applicability and compliance. Many checklists provide additional space to include comments as to the reason for non-compliance or other remarks appropriate to the listed design criteria item.

The HFE evaluator should initiate the use of the checklist with at least some knowledge of the purpose or function of the design item being evaluated. He must have a good working knowledge of the checklist criteria which he will be using. He should determine if the item of hardware has had any previous checklists completed on it, even if the hardware was only in drawing form at the time. The more formal test and evaluation procedure will occur when the item being evaluated is at least in the prototype hardware stage of development. Less formal checklist test and evaluation may take place with hardware drawings or possibly mockups. In any case, the evaluation should take place on a non-interference basis, i.e., the gathering of the checklist data should not interface with the conduct of any other test aspects. The use of the checklist is essentially a static operation, as opposed to a dynamic test which requires observation of operators performing their tasks and equipment properly responding to their manipulation.

The checklist evaluation will result in a verification of the fact that the design item meets all pertinent HE design criteria. If some design criterion is found not in proper compliance, then this information will be provided to design engineering personnel. In some situations there may be satisfactory rationale as to why an item of hardware does

not or should not meet the HE design requirements. In this case a request for deviation to HE design criteria may be submitted to the Navy system program office for their approval.

Use/Validity: This technique is used more often than any other to evaluate design hardware. It is an excellent way to gather quickly qualitative data on system hardware components. However, in order to be of real value, there must be considerable detail contained within the checklist. Depending upon how the checklist is structured, the amount of detail required for review can extend the time required to perform the checklist. Use of the checklist requires more knowledge of basic HE design criteria than system performance requirements.

The disadvantages associated with the use of the checklists are that they produce binary data; the design criteria being verified is either in compliance or not. However, many criteria items have the potential for an exact quantitative evaluation; thus considerable data will be unrecorded. The checklist is used for evaluation of hardware only. In its present, generally agreed-to formats, the checklist will not evaluate personnel skills, quantities, training, technical publications, etc.

The use of this particular technique is strongly advised for all DT&E programs. If not used, there is significant risk that lack of critical design compliance requirements will be overlooked. It is also recommended that the HFTEMAN (Section 5.1.7) be reviewed prior to developing any new program unique checklists.

References:

a) Air Force, Personnel Subsystems Specification. SAMSO Exhibit 68-19, September 1968.

b) Air Force, Test Plan for Category II Testing of System 416M, Prepared by 416M Test Force, Hanscom AFB, November 1963.

c) Army, Human Factors, Army Test and Evaluation Command, Aberdeen Proving Grounds, MTP-6-3-525, AD 728 824, July 1971.

d) Army, Human Factors Engineering, Army Test and Evaluation Command, Aberdeen Proving Grounds, MTP-2-3-516, AD 871 909, May 1970.

e) Army, Human Factors Engineering, Army Test and Evaluation Command, Aberdeen Proving Grounds, MTP-5-2-545, AD 876 199, July 1970.

f) Hattendorf, G. A., et. al., C-141A Category II Systems Evaluation, Technical Report 65-38, Air Force Flight Test Center, Edwards AFB, July 1966.

g) Meister, D., Human Factors: Theory and Practice. New York: Wiley, 1971.

h) Myers, L. B., et. al., Guidebook for the Collection of Human Factors Data, Report PTB 66-3, AD 631 023, HRB-Singer, Inc., Pennsylvania State College, January 1966.

i) Root, R., Performance Measures Report, Air Traffic Control Communications System AN/TSQ-47, CR-62-548-9, Defense Electronics Products, RCA, Burlington, Mass., November 1962.

j) "Human Engineering Design Checklist", WDL-TR-1968A, AD 829 426, Philco-Ford Corp., Western Development Lab., May 1964.

Additional data on this technique as compared with other manual observation techniques may be found in Appendix D.

Sample: See following page (Figure 5.1-1).

5.1.4 Specification Compliance Summary Sheet

Description: This is a form that is used to verify that system performance is in accordance with specified HFE requirements. Briefly, the total process of verifying HFE specification compliance is: first to decide the best method to verify the specification requirement (i.e., analysis, demonstration, or

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31 December 1974

a. RED shall be used to alert an operator that the system or any portion of the system is inoperative, or that a successful mission is not possible until appropriate corrective or override action is taken. Examples of indicators which should be coded RED are those which display such information as "no-go", "error", "failure", "malfunction", etc.

b. FLASHING RED shall be used only to denote emergency conditions which require operator action to be taken without undue delay, to avert impending personnel injury, equipment damage, or both.

c. YELLOW shall be used to advise an operator that a condition exists which is marginal. YELLOW shall also be used to alert the operator to situations where caution, recheck, or unexpected delay is necessary.

d. GREEN shall be used to indicate that the monitored equipment is in tolerance or a condition is satisfactory and that it is all right to proceed (e.g., "go-ahead", "in-tolerance", "ready", "function activated", "power on", etc.).

e. WHITE shall be used to indicate system conditions that do not have "right" or "wrong" implications, such as alternative functions (e.g., Missile No. 1 selected for launch, etc.) or transitory conditions (e.g., action or test in progress, function available), provided such indication does not imply success or failure of operations.

f. BLUE may be used for an advisory light, but preferential use of BLUE should be avoided.

5.2.2.1.19 Flashing Lights - The use of flashing lights shall be minimized. Flashing lights may be used only when it is necessary to call the operator's attention to some condition requiring action. The flash rate shall be within 3 to 5 flashes per second with approximately equal amounts of ON and OFF time. The indicator shall be so designed that, if it is energized and the flasher device fails, the light will illuminate and burn steadily (see 5.3.2.4).

5.2.2.2 Legend Lights -

5.2.2.2.1 Use - Legend lights shall be used in preference to simple indicator lights except where design considerations demand that simple indicators be used.

5.2.2.2.2 Color Coding - Legend lights shall be color coded in conformance with 5.2.2.1.18 and, where applicable, shall be further coded as to function by location, size, and flash coding. Legend lights required to denote personnel or equipment disaster (FLASHING RED), caution or impending danger (YELLOW), and master summation, go (GREEN) or no-go (RED), shall be discriminably larger, and preferably brighter, than all other legend lights.

COMPLIANCE			COMMENTS & DISPOSITION
YES	NO	▷	

Figure 5.1-1: Sample MIL-STD-1472 Checklist Page

quantitative data), second to perform the analysis/test and third to document the results. In any case, reports are written as to the analysis or test results. The Specification Compliance Summary Sheet is a way of summarizing this compliance or lack of compliance.

The evaluator needs first to have a thorough knowledge of all HFE aspects of the contract statement of work and the accompanying system specifications. In particular, he should understand the specification Section 4.0 requirements (quality assurance/testing).

After the test, demonstration, or analysis has been performed and reported, the summary sheet form is completed. The form contains a space to indicate the specification number and complete section being verified. Space is provided for a summary of the test/analysis results. Signature blocks are provided for persons preparing the summary sheets and approving the verification of specification performance.

Use/Validity: This technique is used by only a few HFE T&E organizations. However, this lack of use is not an indication of the need for this type of evaluation. The contract and related system specifications are by far the most important program requirements (Section 2.1). This technique is unique in that it zeros in on these important requirements, rather than concerning itself with T&E of indirect system requirements.

The Specification Compliance Summary Sheet is an excellent way to verify the Section 4.0 specification requirements. The only disadvantages associated with the use of this form are in the large amount of time required to fill it out. The effort preceding the use of this form may be considerable but that effort is a part of the already existing HFE T&E

program. If this technique is not used, there is a risk that some important aspect of HFE design criteria may be overlooked both by designers and by test observers.

Reference: Additional data on this technique as compared with other manual observation techniques may be found in Appendix D.

5.1.5 Technical Order Functional Evaluation

Description: As its title would indicate, this technique is designed to evaluate technical orders or publications pertaining to the test. The technique is based on the use of a form to be completed by the test observers while they are performing their other direct observations of the test. The technical publications must be evaluated as to their usefulness and adequacy in three areas:

a) Job Instructions
b) Training
c) Job Performance Aids

Job Instructions tell how to accomplish a task by providing the step-by-step procedures along with the necessary illustrative drawings.

Most technical publications which require validation or verification provide support for training.

There are three major types of job performance aids identified as follows:

a) Job Guides (including inspection guideline manuals). These guides contain instructions for fixed-procedure tasks such as checkout, adjustment, removal, and replacement.
b) Fully Proceduralized Trouble Shooting Aids spell out the steps to follow in isolating malfunctions to a

replaceable or repairable unit. The steps start with observable symptoms of malfunction.

c) Troubleshooting Decision Aids provide diagrammatic and supporting textual information which will help the technician decide what steps to take in isolating malfunctions to a replaceable or repairable unit.

The following sample evaluation form (Figure 5.1-2) is structured so that the first three questions require two judgements: one dealing with the category of the section being evaluated and the other as to the adequacy. The two questions are to be answered by the test evaluator/observer, as well as the test participants. The remaining questions (4 through 7) deal with the qualitative characteristics of the T.O.

Most sections of the form are self-explanatory, however, the following sections should be completed as indicated:

Evaluator: Identify individual(s) interviewed or those contributing to the evaluation.

Paragraphs Evaluated: List only those paragraphs for which the evaluation applies. In some cases, this can be done in large blocks. There will be some events where several separate forms will have to be completed.

T.O. Verification Personnel Requirements: When verification is performed, the names and rate (rank) as well as skill code of the participants is required.

Prior to conducting this type of evaluation, the observer or evaluator must have a knowledge of the technical manual he is to evaluate. He must also be familiar with estimated system and operator/maintainer performance. The total technical

E-3A

TECHNICAL ORDER FUNCTIONAL EVALUATION

ASSESS THE USABILITY OF THE IDENTIFIED PARAGRAPHS FOR INSTRUCTIONS, TRAINING, AND/OR JOB PERFORMANCE AIDS. (SEE INSTRUCTIONS ON REVERSE SIDE)

T.O. NUMBER:____________________ TITLE:______________________________

EVALUATOR:______________________________ DATE:____________________

PARAGRAPHS OR SECTIONS EVALUATED: (GIVE NUMBER AND SUBJECT)

NOTE: PARAGRAPHS OR SECTIONS COVERED SHOULD BE CONSECUTIVE AND GROUPED SO THAT ANSWERS GIVEN APPLY TO ALL PARAGRAPHS LISTED.

T.O. VERIFICATION PERSONNEL REQUIREMENTS

NAME	AFSC	NAME	AFSC

CONDITIONS AT VERIFICATION: (INCLUDE EQUIPMENT INVOLVED, WHERE PERFORMED, ETC.)

EVALUATION: (USE ADDITIONAL SHEETS FOR COMMENTS)

1. DO THE PARAGRAPHS CONSITUTE JOB INSTRUCTIONS? YES___ NO___
   IF YES, ARE THEY ADEQUATE? YES___ NO___
2. SHOULD THE PARAGRAPHS BE USED FOR TRAINING? YES___ NO___
   IF YES, ARE THEY ADEQUATE? YES___ NO___
3. DO THEY CONSITUTE JOB PERFORMANCE AIDS? YES___ NO___
   IF YES, ARE THEY ADEQUATE? YES___ NO___
4. ARE THE STEPS IN LOGICAL SEQUENCE AND DO THE ELIMINATE BACK TRACKING WHERE POSSIBLE? YES___ NO___
5. DID THE INDIVIDUALS DEMONSTRATING THE OPERATION EXPERIENCE ANY DIFFICULTY AS EVIDENCED BY ERRORS, TOO MUCH TIME, OR NEED FOR ASSISTANCE? YES___ NO___
6. ARE THE FUNCTIONS DESCRIBED SUFFICIENTLY NEW OR COMPLEX AS TO REQUIRE TRAINING? YES___ NO___
7. IS IT NECESSARY TO PROVIDE ADDITIONAL BACKGROUND OR SUPPLEMENTARY INFORMATION IN ORDER FOR THE USER TO UNDERSTAND WHAT?, HOW?, WHEN?, WHERE? ETC.? YES___ NO___

Figure 5.1-2: Sample Technical Order Functional Evaluation Form

order functional evaluation process will result in either verification of the technical data or revisions or recommendations for new technical data. These revisions will be coordinated with the publications writers.

Use/Validity: Depending on the scope or charter of the HFE T&E effort technical order evaluation may or may not be performed. If it is performed (by HFE personnel), it may be accomplished at any time with the evaluation of any evolving systems (as opposed to future or existing systems). The effort required to perform this evaluation is relatively low and it is therefore recommended as a task to be accomplished by HFE or other personnel. Failure to perform this evaluation can result in several maintenance and operational mistakes that would otherwise have been avoided. The cost to perform the evaluation must be considered to be relatively low, particularly compared to the potential cost of the mistakes.

References:

a) Alter, F. H., Ground Electronics System for WS-133B (Minuteman), PSTE Plan, MOP PD 0060, Sylvania Electronic Systems, Minuteman Program Office, Waltham, Mass., March 1964.

b) Lathrop, R. C., et al, Evaluation of the HF Aspects of the GAM-77 (Hound Dog), APGC-TN-60-19, AD 236 953, Human Factors Office, Air Proving Ground Center, Eglin AFB, April 1960.

c) Martin Co., PSTE Test Cycle Report on Missile SM 68-11, CR-63-43, AD 405 382, Denver, Colorado, February 1963

d) Martin-Marietta, Titan II Category II Observer/Evaluator Handbook: PSTE Operating Procedures: Maintenance, Logistics, etc., for SM-688, Titan II, Denver, Colorado, July 1963.

e) Potempa, K. W., "Automated Readability Index to Determine Reading Difficulty," A Catalog of Human Factors Techniques for Testing New Systems, AFHRL-TR-68-15, February 1969.

Additional data on this technique as compared with other manual observation techniques may be found in Appendix D.

Sample: See evaluation form on following page.

5.1.6 Human Performance Reliability Testing

Description: The method or approach employed in the use of this technique is simply direct observation; the purpose is to record test participant errors. This testing may occur at any time during direct observation testing. As in the case of the direct observation technique (Section 5.1.1) the observer must first become familiar with the anticipated man/machine performance.

In all probability the test observer will wish to develop categories of errors to assist with his evaluation of the test error data. Special data sheets may be developed for both recording and categorizing error data in one operation. The most valid test data will be obtained with large subject or participant populations and when several test replications are performed. As in any test, the subjects should be trained and motivated as to their expected participation in the test. The observer may wish to gather both error data and time data if test conditions exist that will allow this. Several observers may be necessary if several test subjects are used and it is necessary that all errors are noted.

Use/Validity: Most human performance testing involves the gathering of time data from test participants. Testing for operator/maintainer errors tends not to be performed because of the problem of not knowing what standard or specified error criteria to test to. That is to say, if testing determines a particular error rate, there is no way of knowing if that error rate is either bad or good. Few valid human performance reliability (HPR)

estimates exist today. This is not to say that human performance reliability should not be done. On the contrary, an accurate data base of field generated HPR estimates is sorely needed.

The major problem in gathering or generating this sort of human performance data is to derive immediate use or benefit from it. If only a small amount of HPR data is obtained, it cannot be usefully compared to any existing data banks. The recommended use of most data bank data is misleading and the data itself is erroneous. If a large enough amount of data is gathered to be useful, the cost of the effort must be extremely high. A large amount of HPR data is necessary to determine accurately the effects of various test variables. An HPR of .999 implies at least 1000 test replications. In many cases, the effects of test variables will not be noticeable until four significant figures are obtained, i.e., 10,000 test replications/subjects.

In spite of the high costs implicit in obtaining HPR test data, it is to be encouraged. More emphasis is needed on operator/maintainer reliability. If extensive HPR testing is not possible, error data should still be recorded with the hope that experienced evaluator judgment can be used along with the limited available data to determine significant error effects. This effort is appropriate to MIL-H-46855, paragraph 3.2.4.3, "Failure Analysis", compliance.

Reference: McCalpin, J. P., and Miles, J. L., Determining Human Performance Reliability with Infantry Weapons: Part One, Technical Memorandum 22-74, U.S. Army Human Engineering Laboratory, Aberdeen Proving Ground, October 1974.

Additional data on this technique compared to other manual observation techniques may be found in Appendix D. See also Section 5.2.2, Human Initiated Failures.

5.1.7 Human Factors Test and Evaluation Manual (HFTEMAN)

Description: HFTEMAN must be considered as considerably more than an HFE T&E technique. It is a human factors test and evaluation manual that is designed to assist the HF engineer in the areas of test plan preparation, test conduct, test data evaluation and analysis, and test report preparation. The HFTEMAN consists of two documents: the first contains detailed HFE test data and the second is a guide book supplement that contains specific HFE design criteria.

The procedure of using HFTEMAN may be considered as a five step process. This procedure is well detailed on the first few pages of the manual. The first step requires that test items be classified as to vehicles, weapons, electronics, etc. The second step is to identify both the user functions and tasks related to this type of equipment; in other words, a selection is made of what to evaluate and the criteria to be used in the evaluation tests. The third step decides what human factor considerations and what item components are relevant. The test observer should review the task list and test item design description to identify which of the test item components presented in the matrix apply to the item under test, and which human factors considerations are important. In the fourth step the test evaluator goes from the cells of HF considerations/task item components to cells containing the exact test criteria as indicated on a separate (opposite) page. The last step is to prepare the HFE test plan which includes an "objective" (taken from HFTEMAN), "criteria" (taken from HFTEMAN), and "methodology" (taken from the HFTEMAN Supplement). The "data required" also is provided in both the HFTEMAN and HFTEMAN Supplement.

It is recommended that the test observer be thoroughly familiar with the HFTEMAN contents before he starts this procedure. The end products of this effort should be both an itemized listing

of all HFE system deficient items and a general feeling of pilot or other operator acceptance of the hardware item.

Use/Validity: HFTEMAN may be used on any program at any time during the program evolution. HFTEMAN is of more than normal value in that it provides both the basis on which to build an HE checklist (Reference Section 5.1.3) and all of the rest of the necessary HFE T&E planning and conduct.

HFTEMAN has broad applicability. No special test equipment is required to use with this technique and it will be of use with any military system. If HFTEMAN is not used, the appropriate HFE test planning must be based on other less coordinated resources.

HFTEMAN has derived from the U.S. Army TECOM Human Factors Engineering Data Guide for Evaluation (HEDGE). The Army guide has been used successfully since its publication in 1974.

Reference:

a) HEDGE: Human Factors Engineering Data Guide for Evaluation. U.S. Army Test and Evaluation Command, Aberdeen Proving Ground, March 1974.
b) Kagerer, R. L., and Weiss, E. C., Development of a Checklist and Guidebook for HF Evaluation of General Equipment, Final Report 30 June 66-1, AD 827 808L, Matrix Corp., January 1968.
c) Navy: Human Factors Test and Evaluation Manual (HFTEMAN), Vol I Data Guide, Vol II Support Data, Vol III Methods and Procedures, TP-76-IIA,B,C, Pacific Missile Test Center, Point Unger, CA, April 1976.
d) Navy: Human Factors Test and Evaluation Manual (HFTEMAN), Video Tape, Pacific Missile Test Center, Point Under, CA, 1976.

Additional data on this technique as compared with other manual observation techniques is contained in Appendix D.

5.1.8 G-2/G-5 Anthropometer

Description: These are two anthropometric devices which may be used as models of various size or percentile crewmen in order to check the adequacy of workstation geometry. They may be regarded as adjustable representations of the more critical crew dimensions. Each device is more analogous to a stick figure than to an anthropometric dummy. They may be adjusted to the 95th, 98th or any desired percentile dimensions for several of the more important crew size parameters.

Use/Validity: The G-2 anthropometer may be used at any crew station. The G-5 is designed primarily for use as an escape envelope measuring device. The total procedure of verifying critical anthropometric parameters can be quite tedious when using just engineering drawings and HE design criteria standards. This analytical process is complex and prone to errors. The use of these devices greatly simplifies the process of calculating the crewmen's required reach or escape envelopes. The use of actual crewmen to test these critical envelopes is somewhat impractical because of the difficulty in obtaining personnel with the required dimensions for each of the pertinent anthropometric parameters.

Somewhat similar devices, such as "compound goniometers", have also been developed at NADC's Crew Systems organization to measure (after the fact) cockpit geometry.

References:

a) Gregoire, H. G., and Barnes, J. R., Cockpit Anthropometric Survey of Model A-4C, A-6A, A-7E, AV-8A, F-4J, F-8D and OV-10A Airplanes, NATC-ST-;20R-71, AD 890 283L, Naval Air Test Center, July 1971.

b) Navy. Investigation of A-4 Aircraft Escape System Clearance Envelope, NATC, ST-53R-72, AD 893 283L, Naval Air Test Center, February-March 1972.

Additional data on this technique as compared with other manual observation techniques is contained in Appendix D.

5.1.9 Terrain Visibility Definition

Description: With the participant (pilot) seated in the aircraft (or mock-up) cockpit and the aircraft in a horizontal flight attitude, direct measurements of the canopy sill vertical and horizontal visual angles are made with a surveyor's transit. The detailed procedure is as follows:

1. The transit is leveled in front of the aircraft and the over-the-nose visual angle is determined. This visual angle is the angle existing between the horizontal vision line and the down vision line (see Figure 5.1-3a).

2. The eye line is established from the down-vision-line instrument station and then projected and drawn on the floor under the aircraft to establish an eye line. The eye line will fall approximately on the longitudinal midline of the aircraft.

3. The transit is then moved to the side of the aircraft and sighted on the pilot's eye. The transit is depressed until it intersects the eye line on the floor. This point of intersection is designated the visual reference point (VRP). See Figure 5.1-3b. The VRP is located on the ground directly beneath the eye of the pilot.

4. The pilot then uses an engineer's hand level to plot the visual points over the sill, from 0^{0} to 180^{0} positions. These points are worked on the floor (ground) by a second person.

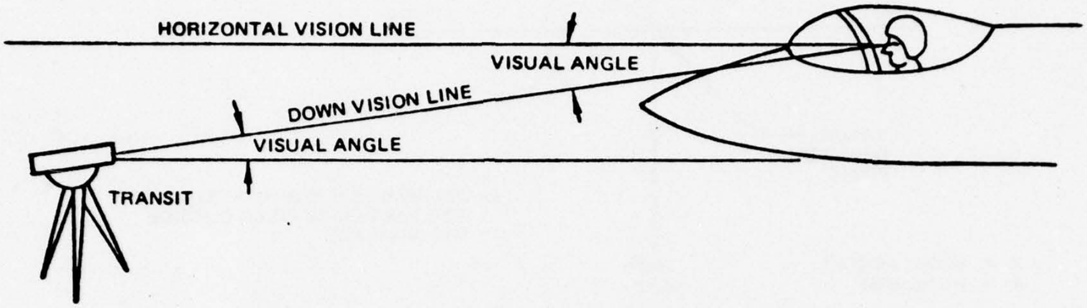
5. The transit is then set up over the VRP, and the horizontal visual angle is then recorded for each viewable point (see Figure 5.1-3c). The distance from the visual reference to each viewable point is also measured. This total procedure establishes the following four parameters (see Figure 5.1-3d):

a) horizontal angle
b) horizontal distance from pilot's eye to a marked point
c) vertical distance from pilot's eye to a marked point
d) slant range from pilot's eye to marked point

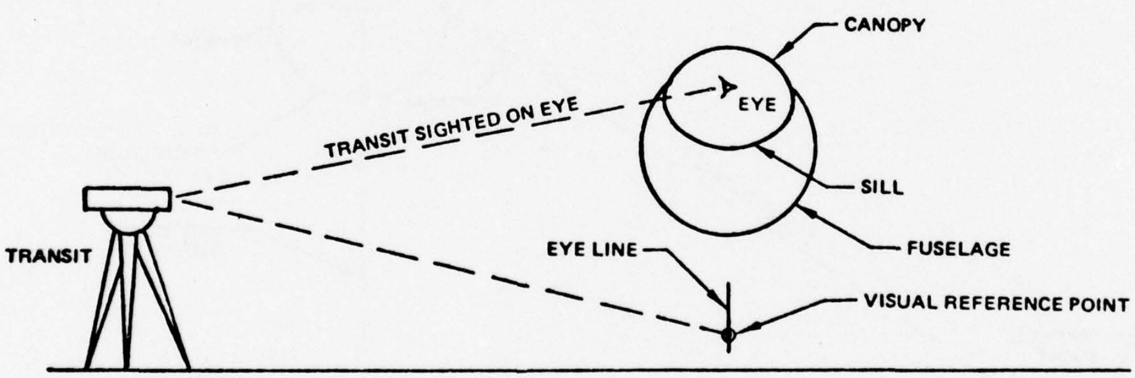
<u>Use/Validity</u>: Using the data obtained from the preceding measurement procedures, the following parameters can be calculated:

a) vertical angles for the visual field outside the aircraft (see Figure 5.1-3d).
b) the horizontal and vertical plot of the blind zone and viewable area.
c) It is also possible to develop tables for various altitudes which can be used to compute total actual ground area visible to the pilot while in horizontal flight.

This technique has been used on the RF-101 and RF-4C aircraft, but it is in no way limited to existing aircraft. A mockup of the cockpit configuration is sufficient to calculate the necessary visual geometry parameters. Early knowledge of the pilot's (or crewman's) visual envelope is essential to determination of the total aircraft system performance. Without the use of this technique, it would be unnecessarily difficult to compare on a quantified basis the various aircraft's cockpit visual field capabilities.

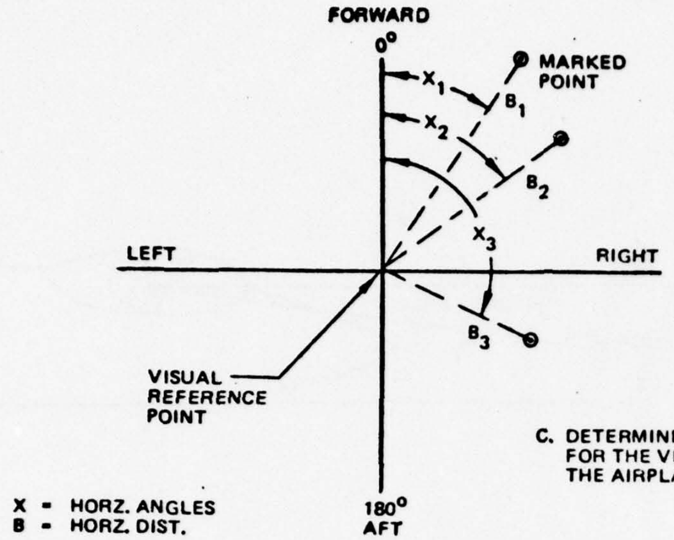


A. DETERMINING THE OVER-THE-NOSE VISUAL ANGLE

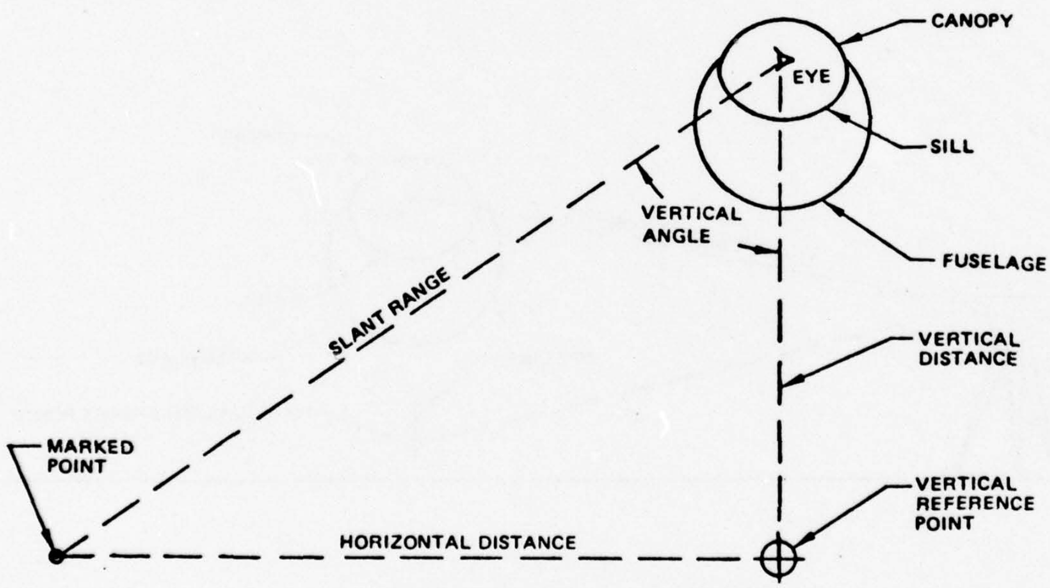


B. DETERMINING THE VISUAL REFERENCE POINT

Figure 5.1-3: Terrain Visibility Definition



C. DETERMINING HORIZONTAL ANGLE FOR THE VISUAL FIELD OUTSIDE THE AIRPLANE



D. DETERMINING VERTICAL ANGLES FOR THE VISUAL FIELD OUTSIDE THE AIRPLANE

Figure 5.1-3: Terrain Visibility Definition (Continued)

Reference: Collins, L. R. and Benny, J. C., Cockpit Sill Visual Angle and Terrain Visibility Definition for RF-101 and RF-4C Aircraft, McDonnell Company Report F-179, March 1967.

Additional data on this technique as compared to other manual observation techniques is contained in Appendix D.

5.1.10 Environment and Performance Measuring Equipment

Description and Use: There are several different items of test or measuring equipment that are extremely useful to the HFE test observer. A few of these T&E tools are presented in separate sections, but most are included here. The following subparagraphs indicate the item of HFE test equipment along with a brief description of its use:

a) Photometer. Measures ambient illumination over a range of levels from approximately .005 to 25,000 foot-candles. This is an extremely useful tool. It is particularly valuable for verifying specification compliance with light level requirements. Sophisticated mockups or prototype equipment/facilities are required for the proper use. Most photometers are relatively easy to use.

b) Spot Brightness Meter. Measures small area brightnesses in foot-Lamberts within angles of approximately one degree or less. This tool is most useful for measuring prototype hardware display brightness such as from LED's or CRT's. Specification compliance may be verified with the spot brightness meter.

c) Sound Level Meter and Analyzer. Measures sound in the approximate range from 10 to 150 dB for standard weighted noise curves. The analyzer provides octive band analysis for the more critical speech range center frequencies. Specification compliance in terms of noise curves and speech interference levels may be verified with this equipment. Hazards to test personnel may be checked prior to overexposure conditions. Most sound level meters are relatively easy to use.

d) Vibration Meter and Analyzer. Measures amplitude and frequency components of complex vibrations. The analyzer may be used to determine amplitudes at selectable frequency bands in a range from 2.5 Hz to 25 KHz. Potential vibration hazards to test participants may be checked before actual test exposure. Specification compliance may also be verified.

e) Thermometer. Measures air, surface, or liquid temperatures. May provide a digital readout in either Celsius (centigrade) or Fahrenheit. Should include capability for attachment to several temperature sensor probes.

f) Anemometer. Measures local air flow in the range of 0 to 1000 ft/minute. This device is most useful for determining crew comfort conditions.

g) Hygrometer or Psychrometer. Measures relative humidity using the wet and dry bulb thermometer method. This device is also very useful for determining conditions for crew comfort.

h) Gas Tester. Permits convenient short-term sampling and evaluation of many toxic gases, vapors and fumes.

i) Force, Torque and Dimension Kit. Various instruments for measurement of a wide variety of operator or equipment forces, torques and distances. The force measurement limits should be from 1/4 oz. to 250 lbs. Torque measurement should range from 1/2 in-lb to 160 ft-lbs. A tape measure should be capable of measuring distances up to 50 feet. Scales should also be for measuring centimeters, millimeters, inches and fractions of inches. A protractor is useful for angular measurement.

j) Anthropometry Instrument Kit. Allows measurement of significant body dimensions using the anthropometer, spreading calipers, sliding caliper, gonometer and tape measure. The measurement of test participants is critical to the evaluation of workspace layouts, particularly when egress and ingress are important considerations. Care should be taken to insure the proper measurement procedures are adhered to while obtaining participant anthropometric data.

References: Additional items of environmental and performance measuring equipment are listed in Appendix D. These items include the G-5 anthropometer, physical measurement, motion pictures, sound tapes, video tapes, photographs and event recorders, which are also presented in separate sections of this guide.

Most of the above equipment may be obtained in kit form for use in HFE T&E field operations. The equipment is packaged into large carrying cases along with the appropriate cables, batteries, operating manuals, test equipment, and expendables.

The following two reports include the use of environment measuring equipment:

a) Air Force, Category II System Development Test and Evaluation of the 482L Emergency Mission Support System, PSTE, APGC-TR-65-61, AD 476 172, Vol. III, Deputy for Test Operations, Air Proving Ground Center, Eglin AFB, December 1965.

b) Martin Company, PSTE Test Cycle Report on Missile SM68-11, CR-63-43, AD 405 382, Denver, Colorado, February 1963.

5.2 System Measurement

5.2.1 System Records Review

Description: There are a number of typical test and evaluation program records that may be useful for review by the HFE personnel. This technique, the review of system T&E records, is unique in that there is no direct contact between the test evaluator and the test participants. All that is required on the part of HFE evaluators is to obtain permission to review the existing test records and to go ahead with the tedious task of looking through them. The evaluator should, of course, have some sort of system knowledge to know what he is looking for in terms of anticipated human performance. Typically, system records will contain test logs, maintenance records, and debriefing records.

The HFE evaluator may find data on equipment operation problems, technical publication inadequacies, human initiated errors, and training inadequacies.

Use/Validity: This technique is best used for gathering man-machine performance data. Because the HFE does not actually observe the test, it is doubtful that sufficient evaluation can reliably take place by reading a word description of what occurred. Human performance tests may have to be scheduled for the purpose of formal observation by HFE personnel.

The problem with a review of test records is that they tend not to be designed for gathering human factors data. What the HFE is able to obtain from these records may be misleading. There is significant risk that HFE problems that could be readily apparent by direct observation, are unobserved or obscured by other less significant test data. In order to enhance the value of system records review, the personnel who initiate these records should be indoctrinated in the value of HFE and HFE T&E.

It is generally agreed that the use of this technique is not required. It is recommended that it be performed only when direct HFE observation is not possible. The debriefing records should be the most useful of all the system records normally available.

References: This technique has been used to a limited degree on the E-3A (AWACS) program. The following references include information on system records review associated with other programs:

a) Majesty, M. S., Human Factors Concepts for Testing Complex Man/Machine Systems, Headquarters Ballistics Systems Division, AFSC, June 1961.

b) Meister, D., and Rabideau, G. F., Human Factors Evaluation in System Development, New York: Wiley, 1965.

c) Peters, G. A., and Hall, F. S., Missile System Safety: An Evaluation of System Test Data (Atlas MA-3 Engine System), ROM 3181-1001, R-5135, Reliability Operations - Human Factors, Rocketdyne Engineering, March 1963.

5.2.2 Human Initiated Failures

Description: A special form or forms may be provided to record only test participant errors. In order to do this properly, the test observer must be knowledgeable of the system procedures to the extent that he will notice operator or participant errors. The form requires the following information: where and when the error occurred; a description of exactly what the error was; and estimates as to the cause of the error, both by the observer and the participant. Possible causes may be presented in a short check list format (e.g., fatigue, environment, equipment design, etc.) Once this form is completed, it should be used to make recommendations to design engineering or other organizations to modify the man-machine interface design, or improve training, etc. The error data should also be compiled in a human performance reliability data bank.

Use/Validity: The major problem with the use of this type of error reporting technique is in being at the right place at the right time to observe the error. There is an extreme reluctance or the part of participants to report their own errors. In some instances, observers are even hesitant to report operator errors. This is particularly true if the error is quickly corrected. The solution to this problem is proper indoctrination and motivation to the benefits of error reporting. Test observers must be looking constantly for participant mistakes and must be thoroughly familiar with the test participant (operator) required tasks.

This technique is particularly appropriate to MIL-H-46855 paragraph 3.2.4.3, "Failure Analysis", compliance.

This technique has been used on the Air Force E-3A (AWACS) program. It is easy to use in terms of the time and effort required to complete the error analysis form. Additional evaluation of this technique as compared to others is in Appendix D. The following Figure 5.2-1 illustrates a sample format for the form.

References: Human Performance Reliability Testing Technique, Section 5.1.6.

a) Blanchard, W. H., Recording Battle Staff Performance, TM-2593/000/00, AD 620 662, System Development Corp., August 1965.

b) Meister, D., and Rabideau, G. F., Human Factors Evaluation in System Development, New York: Wiley, 1965.

c) Myers, L. E., et al Guidebook for the Collection of Human Factors Data, Report PTB 66-3, AD 631 023, HRB-Singer, Inc., State College, Pennsylvania, January 1966.

5.2.3 Test Participant History Record

Description: This is not a direct test technique but rather a method of improving the test evaluation process. The Test Participant History Record form is used to collect data on personnel participating in HFE tests. This form should be completed before participation in the tests, if possible. Otherwise, the form may be completed as part of the post-test interview. The sample form included in the following pages (Figure 5.2-2) emphasizes participant training, experience in systems similar to the one being tested, and participation in previous testing related to the same overall system presently being tested. This form may need to be modified to suit the needs of the particular test situation.

Use/Validity: The purpose or use of this form is to assist in the evaluation of the obtained test data. For example, if the test participant has had little or no experience in performing tasks similar to the ones he has been given to do as a test participant, and he does very well, then the conclusion is that the man-machine

OPERATOR ERROR ANALYSIS

INSTRUCTIONS:

1. ATTACH TEST CONDUCTOR'S OPERATOR ERROR LOG TO THIS SHEET.
2. TEST CONDUCTOR COMPLETE SECTION A.
3. OPERATOR COMPLETE SECTION B.
4. PSTE REPRESENTATIVE ATTEND TWG REVIEW AND COMPLETE SECTION C.

SECTION A – TEST CONDUCTOR DATE: ______________

1. FLIGHT NO. ______________ 2. FLIGHT DURATION ________ HRS ________ MIN.
3. FLIGHT TIME WHEN ERROR OCCURRED ______________________________
4. DESCRIBE ERROR: (WRONG SWITCH ACTION, LATE SWITCH ACTION, INCORRECT COMMUNICATION, ETC.)

____

____

____

5. CAUSE OF ERROR: IF "UNKNOWN," REQUEST OPERATOR TO PROVIDE COMPLETE DETAILS IN SECTION B).

____

____

____

SECTION B – OPERATOR

1. PLEASE STATE THE CIRCUMSTANCES/CONDITIONS YOU FEEL RESULTED IN ABOVE ERROR (USE CONTINUATION SHEET IF NECESSARY).

____

____

____

____

2. WAS THE ERROR DUE TO FATIGUE RESULTING FROM THE TEST MISSION?

CHECK: YES _______ NO _______

SECTION C – TWG REVIEW (CONSULT WITH OPERATOR AND TEST CONDUCTOR AS NECESSARY)

1. ERROR WAS DUE TO:

_____ ENVIRONMENT (LIGHTING, TEMPERATURE, TURBULENCE, ALTITUDE, ETC.)
_____ EQUIPMENT DESIGN/FUNCTION/ARRANGEMENT
_____ SOFTWARE DESIGN/FUNCTION
_____ INADEQUATE PROCEDURE PRESCRIBED (INCLUDING T.O.)
_____ WRONG SKILL FOR TASK
_____ OPERATOR NOT PROPERLY TRAINED
_____ EXCESSIVE OPERATOR WORKLOAD
_____ OTHER (EXPLAIN IN ITEM 2)

2. ATTACH A CONTINUATION SHEET DESCRIBING THE CONTRIBUTING FACTOR(S) CHECKED ABOVE, ALONG WITH RECOMMENDED CORRECTION, IF ANY.

Figure 5.2-1, Human Initiated Failure Form

PS TEST PARTICIPANT HISTORY RECORD

NAME/RANK ________________ DATE ________

AFS/AFSC ________________ TIME IN AFS ________

TRAINING

COURSE	DATE	PARTICIPATION IN PREVIOUS TESTING

RELATED EXPERIENCE

Figure 5.2-2: Sample Test Participant History Record

interface being tested has been well designed and developed. If, on the other hand, his performance is poor, the problem may or may not be due to poor man-machine interface design. A more experienced test participant will have to be given the same tasks to perform. The time and effort it takes to complete the form is small, and the potential value of having the test participant's significant history is large. This technique has been used on the Minuteman Personnel Subsystem Test and Evaluation (PSTE) program.

References:

a) Air Force, Golden Ram Personnel Subsystem Final Report, Atlas "D" Series, Contract AF04(647)-619, September 1961.

b) Air Force, Personnel Subsystem Specification, SAMSO Exhibit 68-19, Headquarters Space and Missile Systems Command, September 1968.

c) Air Force, Test Plan for Category II Testing of System 416M, Prepared by 416M Test Force, Hanscom AFB, November 1963.

d) Lindsey, J. F., Bioastronautics Study of B-58 Training, Category III System Operational Test and Evaluation, APGC-TN-61-8, AD 259 304, Bioastronautics Office, Air Proving Ground Center, Eglin AFB, May 1961.

e) Martin-Marietta, Titan II Category II Observer/Evaluator Handbook: PSTE Operating Procedures: Maintenance, Logistics, etc. for SM-68B, Titan II, Denver, Colorado, July 1963.

5.3 Indirect Manual

5.3.1 Interviews

Description: The HFE T&E interview technique is simply the process of the HFE test evaluator discussing the test events with the test participants. This discussion should be structured in order to insure that the most information is obtained in the least amount of time.

The first step in the process of conducting the interview is to develop a format for asking questions of the participants (interviewees). The format may be structured like a checklist

to insure that all pertinent aspects of the test are considered. The second step is to select an interviewer who has had experience with the system being evaluated. It is important that he has observed the actual test conducted. The next step is to arrange a time to conduct the interview with the test participant.

The interviewee should be questioned about the task he has performed. He should describe what he thinks his test task consists of in terms of his duties and those of others. His opinions should be obtained on the adequacy of the equipment, technical data, logistics and preparatory training.

The interview should be conducted as soon as practical after the actual test, hopefully within a few hours. If possible, the interview should be conducted on a one to one basis rather than one interviewer questioning several participants at one time. The area selected for the interview should be relatively quiet with a minimum of distractions. The time taken to conduct the interview should be less than half an hour. Interviews which are longer than this start to get boring and become an imposition on the interviewee.

The HFE interviewer must take care to insure that he is obtaining the interviewees actual opinions as to the test situations and not what the interviewee thinks the interviewer wants to hear. The participant must be assured that he is not being graded in any way on his responses. The HFE interviewer should try to quickly develop a rapport with participants. If the participant agrees, a tape recording may be taken of the interview. However, whether the participant agrees or not, some individuals tend to be intimidated by the use of tape recordings and caution must be used in this regard.

Specific variations to the general interview technique may be of use for particular situations. For example, considerable test and evaluation data may be obtained from training instructors. They are particularly knowledgeable in regard to student problems with new systems because of inadequacies in the system design.

Another example of an interview technique is the "critical incident technique". The critical incident technique consists of a set of procedures for collecting observations of human behavior in such a way as to facilitate their potential usefulness in solving practical problems. A critical incident is any observable human activity, the purpose and effects of which seems clear to the observer. The five step procedure is basically as follows: a) Determination of the general purpose of the activity; b) Development of plans for collecting incidents regarding the activity and instructions to the persons who are to report their observations; c) Collection of relative objective data; d) Analysis of the data; and e) Interpretation and reporting of the statement of the requirements of the activity. The gathering of the series of incidents consists of inquiry as to most effective or ineffective behavior (or critical incident) of specified activities/jobs. Although the incidents may be secured by interviews, they may also be obtained by written responses.

The end product of the interview is a quantity of test data (facts and opinions) to review and evaluate for the purpose of presenting system problems and recommendations, and in many cases system verification.

Use/Validity: The interview is one of the most significant evaluation methods used. It is a simple, low cost, quickly used technique. Every test involves a certain amount of test data that cannot be obtained through normal observation. Interviews with the test participants draw directly on this type of data and on the knowledge of the presently available system experts. Interviews do not require the use of test facilities. They may be conducted in an area remote from the test site.

The purpose of an interview is to find out either objective facts related to the system about which the interviewee has some knowledge, or subjective facts, attitudes, or opinions about how he feels about some test aspect. The interview must be designed to obtain these facts with as much clarity and accuracy as possible.

The interview attains its greatest value from the relationship which is established between the interviewer and the respondent. In a properly conducted interview, where a genuine rapport is established between the interviewer and the interviewee, it is possible to obtain more detailed and reliable data than from the self-administered questionnaire.

One caution that must be pointed out in the use of interviews is bias on the part of the interviewer or interviewee. Ideally, the interview results in the interviewee supplying accurate information to the interviewer. However, the influence of bias can alter the results to such an extent that the answers are of little or no value in the final analysis. The interviewer may bias the interview by tone of voice, the way in which the questions are phrased, or even by facial expressions. These and other sources of bias can be greatly reduced through recognition of the problem and by training and experience.

Another caution associated with the use of interviews is that they cannot be used as a substitute for direct test observation. They should be used as one of several HFE test and evaluation techniques.

This technique has been used by the services and contractors alike on numerous programs such as Minuteman, E-3A, WX-50 and A7TRAM.

References:

a) Air Force, PSTE Standard Operating Procedure (SOP) for Program 279, Space Command and Control, SAC, ATC, and OOAMA, Bendix, 1963.

b) Air Force, Personnel Subsystem Specification, SAMSO Exhibit 68-19, Headquarters Space and Missile Systems Command, September 1968.

c) Flanagan, J. C., "The Critical Incident Technique", Psychological Bulletin, Vol. 51, No. 4, July 1954.

d) Inaba, K., The Titan II Inertial Guidance System Category II PSTE and Maintenance, Logistics, Reliability and Readiness (PSTE/MLRR) Program, Volume I, Serendipity/A.C. Spark Plugs Coordination Document No. 36, Serendipity Associates, Sherman Oakes, California, September 1963.

e) Army, Man-Material Systems, Questionnaire and Interview Design (Subjective Testing Techniques), TECOM Pam. 602-1, Vol. 1, Headquarters, U.W. Army TECOM, July 1975.

f) Meister, D., and Rabideau, G. F., Human Factors Evaluation in System Development, New York: Wiley, 1965.

Additional information on this technique as compared with other indirect observation techniques may be found in Appendix D.

5.3.2 Questionnaires

Description: The basic tool for obtaining subjective data is the questionnaire. It is the most frequently used and most difficult to construct of the subjective techniques. The questionnaire provides a structured method for asking a series of predetermined questions in order to obtain measurable expressions of attitudes, preferences and opinions. The design of a questionnaire which will produce valid and reliable results requires a measure of skill and experience. Unfortunately, questionnaire design and construction cannot be taught from books; the requirements for each test are somewhat different and present new and different problems. However, there are certain rules and principles of questionnaire design and administration which, when followed, eliminate some of the more common pitfalls which result in faulty questions and invalid results. The following material, especially the references, are intended to provide guidance for planning, designing and administering the questionnaire.

The method of questionnaire design applicable to the types of tests conducted by HFE T&E personnel may be divided into seven logical steps:

a) Preliminary planning.

b) Selection of the question form.

c) Wording of the questions.

d) Formulating the questionnaire.

e) Pretesting.

f) Administering the questionnaire.

g) Quantification and analysis of questionnaire data.

The preparation of a questionnaire requires great care and a background knowledge of the system to be tested. Knowledge also is required regarding the background of personnel to whom the questionnaire will be administered, and the type of analysis which will be made of the results. Too often a questionnaire is prepared with insufficient planning. The problems involved and the weaknesses in the design are frequently not recognized until such time as the results are interpreted.

There are four basic question forms that may be used in a questionnaire:

a) The open-end or free-answer.
b) The dichotomous or two-way.
c) The multiple choice
d) The rating scale.

Each form has its merits and disadvantages of which the questionnaire designer must be aware and must weigh carefully before final selection. No one question form is superior to the others in all cases. In order to select one form over another, the designer must be aware of the advantages and disadvantages of each and choose that form which best meets the needs of the particular test situation.

The most important, and also the most difficult, aspect of questionnaire construction is the wording of the questions. Most authorities agree that faulty or improper wording of questions accounts for the greatest source of error in the questionnaire technique. Errors and distortions in the final data are often caused by misunderstanding and misinterpretation of questions due to use of an improper vocabulary level and ambiguous phrasing. In addition to selecting the question forms and wording the questions, it also is necessary to consider such factors as the sequence of the questions and the format for presentation and data collection. A check must be made of all questions to insure complete and accurate coverage of all data required by the test objectives and test critical issues.

A questionnaire is subject to many variables and must not be assumed to be perfected until it has been subjected to trial use. The pretest provides an opportunity to try the questionnaire out on a small sample of respondents. The results of this trial may then be used to make revisions and improvements as necessary before test administration. The pretest is the final and validating step in the method of questionnaire construction.

The product obtained from administration of the questionnaire consists of subjective words or phrases. This information may be quantified and converted to figures or numbers that can be tabulated and analyzed. The end product of the questionnaire may be a simple frequency distribution of responses to each question summarized in terms of numbers, proportions or percentages. The data may be further summarized to include averages, standard deviations, or correlations. The summaries also may include statistical analyses showing the statistical significance of differences or correlations obtained. These quantified data must then be tabulated and analyzed. The results usually are summarized in tabular form for inclusion in a final report.

When compared to the interview, there are several similarities and differences with the questionnaire. Both the questionnaire and interview should be conducted within a few hours of the test for best results. Both techniques may be conducted away from the test area. Although the questionnaire must be more structured than the interview, the questionnaire may still include open-ended questions. The differences are in that HFE personnel need not be present while the questionnaire is being filled out. The questionnaire is inherently easier to use in evaluation or analysis of the participant responses.

Use/Validity: The questionnaire is a subjective measurement tool for systematically obtaining attitudinal responses from a selected group of individuals. The function of the questionnaire is to communicate information. When properly formatted, it also aids in the tabulation of data and analysis of results. The questionnaire is used to assess a wide variety of qualitative variables such as acceptance, ease of use and preference. It may be administered to small groups of technical personnel, such as those involved in highly controlled engineering tests, or to larger representative cross-sections of service personnel.

Knowledge of individual or group attitudes provides valuable information regarding reactions, feelings, and preferences toward military systems. Since attitudes determine behavior, questionnaire responses of a representative sample of the population permit a reliable estimate of group reactions to systems in actual use. These results also may be used to anticipate and thereby avoid future developmental problems.

The questionnaire is appropriate for use in all types of tests. It should be used to obtain subjective data when objective measurement is not feasible and when qualitative data are needed to supplement objective measurements. However, it should not be used in place of direct observation techniques if observation is possible.

A disadvantage of the questionnaire is that test participants won't respond in writing to the degree that they would in talking in a response to an interview. The effort to write responses to open-ended questions is greater than the effort to talk. Another disadvantage of the questionnaire, compared to the interview, is the inability of the HFE observer to pursue a participant response that is unexpected but potentially fruitful.

One of the most difficult problems to overcome in questionnaire design is the misunderstanding on the part of individuals as to what a questionnaire is and how it should be used. There are those who believe that anyone who can write well and use a little common sense can construct a good questionnaire. The seriousness of this faulty assumption is illustrated by the fact that an improperly designed and poorly worded questionnaire will still yield data in the form of numbers, frequencies and percentages. These numbers are amenable to statistical analysis and may even produce statistically significant findings. The real tragedy is that these erroneous findings may be used to draw false conclusions which, in turn, contribute to faulty critical decisions regarding the utility of an item.

References: Functional description inventories (FDI's) which are discussed in the following section.

a) Air Force, Test Plan for Category II Testing of System 482L, AN/TSQ-47 Emergency Mission Support System, Air Proving Ground Center (AFSC), Eglin AFB, September 1963.

b) Army, Man-Material Systems, Questionnaire and Interview Design, (Subjective Testing Techniques), TECOM Pam 602-1, Vol. 1, Headquarters, U.S. Army TECOM, July 1975.

c) Hattendorf, G. A., et al, C-141A Category II Systems Evaluation, Technical Report 65-38, Air Force Flight Test Center, Edwards AFB, July 1966.

d) Myers, L. B., et al, Guidebook for the Collection of Human Factors Data, Report PTB 66-3, AD 631 023, HRB-Singer, Inc., State College, Pennsylvania, January 1966.

e) Potempa, K. W., "Open-Ended Maintenance Questionnaire", A Catalog of Human Factors Techniques for Testing New Systems, AFHRL-TE-68-5, February 1969.

Additional information on this technique as compared with other indirect observation techniques may be found in Appendix D.

5.3.3 Functional Description Inventory (FDI)

Description: The FDI is a new HFE T&E assessment methodology or special case questionnaire. The FDI requires a series of investigations analyzing the operational functions of crewmembers, with an essential part involving the determination of roles, duties and tasks performed by each crewmember. Subsequent to this, analysis time is provided in order that the crewmembers can judge how important these roles, duties and tasks were for mission success. They also judge how frequent they are performed on a typical mission, how adequate the training has been to insure effective performance of the task, and finally, how effective the particular system has been in accomplishing these operational functions.

Once the approval has been given to use the FDI, the procedural steps to be followed in its development are as follows:

a) Source material is gathered to provide guidelines for selection and working of duties and tasks.

b) Local technical advisors (crewmembers experienced in the particular position under study) review pools of duty and task items for applicability. They also develop additional items as required.

c) A preliminary FDI is developed based on reviewer comments, recommendations and additions to the duty/task list.

d) On the basis of this review, a final FDI is developed.

e) The FDI is distributed to test participants (experienced crewmen) who then fill them out.

f) Statistical computations are generated by computer programs. For example, items of statistical interest are standard deviations as to question responses in order to determine later agreement.

f) System problems, as indicated by the consensus of the crew, are noted for feedback to the existing system development procedures.

<u>Use/Validity</u>: The FDI has been developed in detail by the Naval Air Test Center at Patuxent River. The P-3C, E-2C and S-3A have been evaluated with this technique. There are several advantages to its use. For example, it may be used as a checklist to cover all aspects of the system test. The data obtained in this technique comes from system experts. In turn, the system experts are trained as to what HFE criteria are significant. The technique may be considered extremely thorough.

The disadvantages in using this technique are the time and effort required to develop the questionnaires. They must be unique to each program being tested. The time and effort for the crewmen to complete the questionnaires are also considerable. Of much less consequence, but still to be considered, is the problem of obtaining permission to use crewmen's time, first to develop the questionnaires, and second to complete the questionnaires.

Although not as complete as the FDI, other more generalized questionnaires could be used in place of it.

<u>References</u>: Helm, W. R., <u>Fourth Interim Report - Function Description Inventory as a Human Factors Test and Evaluation Tool: An Empirical Validation Study</u>, SY-127R-76, Naval Air Test Center, July 1976.

Additional data on this technique as compared with other indirect observation techniques may be found in Appendix D.

5.3.4 Personnel Activity Analysis Radio System (PAARS)

Description: The Personnel Activity Analysis Radio System is essentially a direct observation questionnaire technique. It is based on the use of 2-way radios between one HF engineer and several maintenance technicians or crews. It is not intended to be used as an observation technique for formal HFE test and evaluation. It is intended for quick and efficient gathering of human factors data from maintenance operations being performed on certain systems in the operational inventory. Technicians are required to report in from the location of their work. They are asked questions in regard to equipment problems, procedural problems, delays and potential hazards.

The technique requires the use of an off-the-shelf base station, receiver-transmitter with encoder unit, several portable receiver-transmitters, and a battery charger. The portable unit should weigh less than a few pounds and be less than 50 cubic inches in size. The portable unit antenna should not require adjustments and should not interfere with work activities. A concealed or self-contained system is desired. The portable units should also have a hands-off capability for talk-listen after the units are switched on. The base station should have a capability to make a hard-line connection between transmitter-receiver and a tape recorder to permit direct recording of incoming and outgoing communications.

An extremely significant requirement for the use of this system is the permission from security and maintenance control personnel.

Use/Validity: The results from use of the PAARS are in the data gathered for operational evaluation. Maintenance crew task performance, in terms of time required and errors made, are compiled. There is a significant payoff potential in correlating this operational data to formal HFE test and evaluation data.

Although this technique has been used successfully, it is not significantly superior to the more standard direct interview or questionnaire techniques. The PAARS is probably best for determining equipment and tool problems. It obtains an objective response to questions while the data is still fresh in the mind of the technician. The technique saves travel time for the HFE observer or base station operator.

The disadvantages to the use of this technique are in:

a) the HFE observer cannot see the problem or equipment for himself,

b) the technique is limited to use with ground based aircraft maintenance task tests,

c) the technicians must remember to use it or be reminded by the HFE,

d) it requires the full time of an HFE to monitor the base station, and

e) the technique is limited in use for gathering test data alone. It is not useful for evaluation of test data.

This technique was used on the 407L communications system and for B-52 flight line maintenance.

References: Askren, W. B., et al, A Voice-Radio Method for Collecting Human Factors Data, AFHRL-TR-68-10, Air Force Systems Command, Wright-Patterson, January 1969.

Additional data on this technique as compared with other indirect observation techniques may be found in Appendix D.

5.3.5 Cooper-Harper Scale

Description: The Cooper-Harper Scale is a well known technique used to evaluate aircraft handling qualities through the use of pilot ratings. The pilot participants are requested to provide their evaluation of

given flight tasks, subphases, phases, or even the total flight (or mission). As can be seen from examination of Figure 5.3-1, which is the Cooper-Harper aircraft handling qualities rating scale, the technique is basically dichotomous. The pilot decides if the aircraft is controllable for a given task, sub-phase, etc. If the aircraft is controllable he decides if the mission, phase, etc., performance is adequate with a tolerable workload. If not adequate, he chooses (on a scale of three) how bad the major deficiencies are. If adequate, he determines if the performance is satisfactory without the need for improvement. If not satisfactory, he determines (on a scale of three) how bad the deficiencies are. If satisfactory, he determines (on a scale of three) how satisfactory the performance is.

As can be seen from the figure, the descriptions of aircraft handling performance are both clearly and briefly defined. Reference to pilot skill level has been deleted from a previous version of the Cooper-Harper Scale. Pilot judgments as to the handling qualities are to be made on the basis of their own skill. Generally, the pilots requested to use this technique are quite skilled, but any variations in pilot skill should average out by using large populations of pilot test participants.

The qualitative statements as to handling qualities are converted into "quantitative" numbers only for purpose of convenience. The scale of ten is a result of ten categories of evaluation. The scale is ordinal as opposed to equal interval. The use of evaluations halfway between those indicated are acceptable but not encouraged (e.g., ratings of 1 and 1/2, 2 and 1/2, 3 and 1/2,. . . 9 and 1/2).

In addition to obtaining the above Cooper-Harper rating scale data, the HFE evaluator is encouraged to obtain the pilots' comments by way of a questionnaire or interview.

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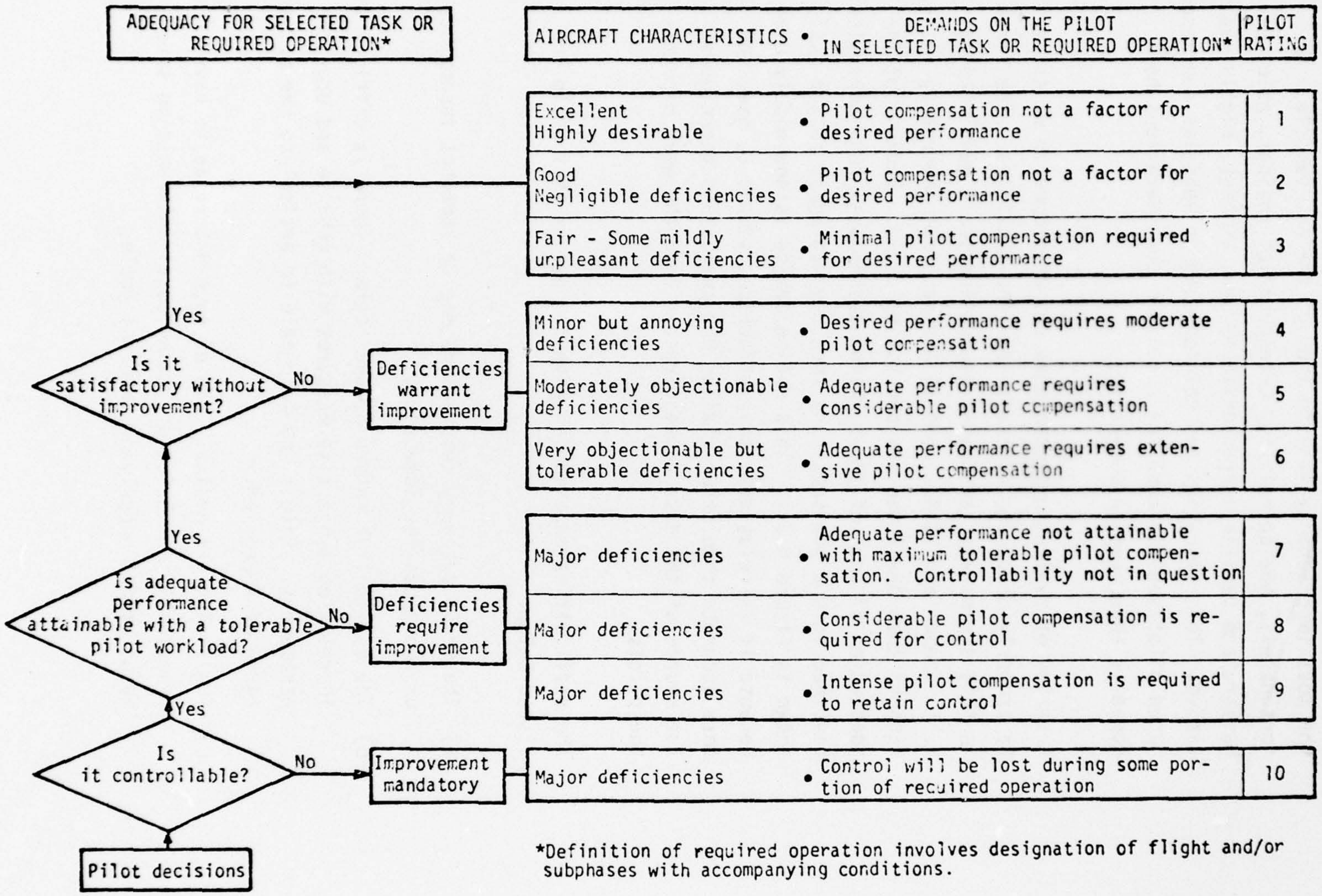

*Definition of required operation involves designation of flight and/or subphases with accompanying conditions.

Figure 5.3-1: The Revised Cooper-Harper Scale (Handling Qualities Rating Scale)

Use/Validity: The pilot test particpant's subjective opinion tends to be the most important evaluation item of the air vehicle. Unfortunately, the correlation between pilot ratings, pilot behavior, and vehicle characteristics are, at best, highly qualitative. This situation has not improved as vehicles and associated pilot/vehicle handling qualities considerations have steadily increased in complexity.

A series of evaluation techniques was developed in an attempt to properly determine aircraft handling qualities. The first in this series was the Cooper evaluation scale developed by G. E. Cooper and NASA. Cornell Aeronautical Laboratory (R. P. Harper) then developed its own rating scale. Because of inadequacies of both of these rating techniques, they were wisely combined into a new scale and then revised again to the scale shown in Figure 5.3-1. This rating device is now widely used because it is relatively cost effective, simple to use, and more accurate than other similar HFE evaluation techniques. The source of the data comes directly from the user experts, the pilots.

The difficulties experienced with the use of this scale are listed below:

a) The scale category descriptors may be somewhat incomplete or ambiguous for some users.

b) The qualitative nature of the scale: There is difficulty in relating subjective measures with vehicle and operator parameters. Pilots may be unable to articulate the primary cause of a problem.

c) The scales are ordinal, and of such nature as to have practically no choice of having equal intervals on some hypothetical underlying interval scale.

d) The scales are subject to misuse by design engineers.

e) The scales are useful for flight handling qualities only.

f) It is difficult to deal with parameters such as transient disturbances (e.g., windshear or subsystem failure) or pilot stress.

If the Cooper-Harper scale is not used for flight handling quality evaluation, the test evaluator must rely on aircraft installed sensor data (e.g., accelerometers) and on pilot interviews and questionnaires.

<u>References</u>:

a) Cooper, G. E., and Harper, R. P., <u>The Use of Pilot Rating in the Evaluation of Aircraft Handling Qualities</u>, NASA TN D-5153, N69-22539, April 1969.

b) McDonnel, J. D., <u>Pilot Rating Techniques for the Estimation and Evaluation of Handling Qualities</u>, System Technology, Inc., Hawthorne, California, AFFDL-TR-68-76, AD-681845, December 1968.

Additional data on this technique as compared with other indirect observation techniques may be found in Appendix D.

5.3.6 <u>Problem Incident Report</u>

<u>Description</u>: This form is used whenever the data source indicates an unsatisfactory condition relating to the operator/maintainer element of the system being tested. The terminology for this technique or form varies. It is often called an "Unplanned Event Record", "Crew Interface Data", or just a "Squawk Sheet". In many instances, this report is completed by the HFE test observer. However, it may be completed by anyone observing HFE related problems. If completed by other than HFE personnel, an interview with the originator is recommended. Frequently, the item can be closed out as the result of the interview. Numbers are assigned to each new Problem Incident Report. Records are kept on each report as they are acted upon by HFE personnel to achieve problem resolution. As a matter of interest and motivation, feedback is provided the incident report originators.

In the initiation of follow-up action, there are at least three paths to follow:

a) If the evaluation determines that no further action is indicated, the rationale for closing out the problem is provided and the report is closed out.

b) The HFE test group will make recommendations as to design, technical publication, maintainability, training, etc., as to solutions to the problems.

c) If the problem is sufficiently serious, additional organizations besides the HFE test group are notified. They may wish to take the lead in solving the problem.

d) The (customer) system program office may also be contacted if the problem is a serious one.

Use/Validity: This technique is easy to use both in terms of effort and time. If well managed, it allows other groups (observers and participants) to provide HFE test data at any time. The system experts may be the data source. The only possible criticism of this technique could be said about any other; it is not sufficient to use this technique alone to do a proper HFE test job. If this technique is not used, there will be more of a burden or obligation on the part of the HFE personnel to find all the HFE related system problems.

This technique has been used on the Air Force E-3A (AWACS) program. Additional evaluation of this technique when compared with others is in Appendix D. The following Figure 5.3-2 illustrates a sample format for the form.

References:

a) Meister, D., and Rabideau, G. F., Human Factors Evaluation in System Development, New York: Wiley, 1965.

b) Peters, G. A., and Hall, F. S., Missile System Safety: An Evaluation of System Test Data (Atlas MA-3 Engine System), ROM 3181-1001, R-5135, Reliability Operations - Human Factors, Rocketdyne Engineering, March 1963.

Additional information on this technique as compared with other indirect observation techniques may be found in Appendix D.

TEST SHEET TITLE			REPORT NO	DATE
RELATED REPORT	VEHICLE TYPE	VEHICLE SERIAL NO(S)	TEST LOCATION	
MAJOR SYSTEM	SUBSYSTEM		COMPONENT PART NO/SERIAL NO	

CID IDENTIFICATION

TITLE

TYPE HE ☐ BIOMED/LS ☐ PP ☐ TRAINING ☐ TECH. PUBS. ☐ SAFETY ☐ M ☐

DEFICIENCY CIRCUMSTANCES/DESCRIPTION/CAUSES (CONTINUE ON SEPARATE PAGE IF NECESSARY)

LOCAL ACTION

RECOMMENDATION

HAZARD CODE, EFFECT AND IMPACT SUMMARY

HAZARD CODE (MIL-STD-882)	POTENTIAL HAZARD EFFECT		MISSION IMPACT		CORRECTION CATEGORY
☐ I	☐ NONE		☐ DELAYS	☐ MAINTENANCE	
☐ II	☐ MAJOR/MINOR DAMAGE	☐ SUBSYSTEM	☐ RESTRICTS	☐ CREW EFFECTIVENESS	☐ MANDATORY
☐ III	☐ MAJOR/MINOR INJURY	☐ PERSONNEL	☐ DEGRADES	☐ SYSTEM PERFORMANCE	☐ DESIRABLE
☐ IV	☐ LOSS	☐ VEHICLE	☐ PREVENTS	☐ MISSION	

HAZARD CODE AMPLIFICATION

CONTACT	ORGANIZATION	M/S	PHONE

DISPOSITION

PROJECT MANAGER	SIGNATURE	DATE

Figure 5.3-2, Sample Problem Incident Report

5.4 Automatic Recording

5.4.1 Motion Pictures

Description: This technique is similar to the use of video tapes. It is the process of filming participant performance as a part of a system test.

As with video tapes, actual prototype hardware or sophisticated mockups should be available to justify the use of this technique. Less sophisticated mockups imply more uncertainty in design, and therefore a greater risk in expending a motion picture effort on unsuccessful concepts.

Trained test participants must be available for observation of their appropriate tasks. The cameraman, and particularly the HFE observer, should be familiar with the test operation being performed. The knowledge of when to take close-in footage of a particular critical task is important. As in the case with video cameras, a dry run is recommended to insure the filming is properly performed. Consultation with all personnel familiar with the anticipated test events is advised.

The following equipment is necessary to implement this technique:

a) camera and (film)
b) lens
c) lights
d) projector
e) screen

A tripod may be required, depending on the test situation.

Permission to use cameras in secure areas must be obtained and the camera equipment and cameraman properly scheduled.

Use/Validity: This technique was comparatively more useful before the development of video tapes. Video tapes are now becoming more popular for that type of test and evaluation process.

However, when compared to all other techniques, motion pictures still offer the advantages of: permanent precise records of observed events, repeated observations of the same event, slow and fast motion study of real-time events, use in hazardous areas, and record of task activities as well as the related background situation. The data gathered may be presented to large groups of people.

The disadvantages are in the cost and effort to provide the proper equipment, particularly for processing and viewing the film. Skilled technicians are generally required for the filming of motion pictures.

Motion pictures are not as useful as video tapes in that they must be processed to be viewed. Instant playback of a film cannot be made to insure the adequacy of that particular test record. After the processing, a projector and screen are required. The film cannot be reused as video tape can. However, the cost of the least expensive movie equipment is less than the least expensive video equipment. The process of recording and presenting observed test tasks in slow motion or fast-action is cheaper with motion pictures.

References: Video tapes.

The following two reports include information on the use of motion pictures in HFE T&E:

a) Adams, J. A. and McAbee, W. H., A Program for Evaluation of Human Factors in Category II Testing of Air Weapons Control System 412L (Phase II Configuration), PGN Document 62-1, Deputy for Bioastronautics, Air Proving Ground Center, Eglin AFB, May 1962.

b) Majesty, M. S., Human Factors Concepts for Testing Complex Man/Machine Systems, Headquarters Ballistic Systems Division, AFSC, June 1961.

Additional information on the technique as compared with other automatic recording techniques may be found in Appendix D.

5.4.2 Sound Tapes

Description: The use of this technique is now so common that a description is somewhat superfluous. Tape recorders are now both inexpensive and portable. They are used extensively for tasks other than formal test observation. Their use in HFE T&E is somewhat like that of video tapes but without the restrictions of size, security, transportation and cost.

Test observers commonly use sound tape recorders to maintain a complete record of test conversation and events. Test notes may be verbally entered by the observers themselves. The recorders may also be used to record participant interview comments. The recorder may be linked into the intercommunication system if such is used as a part of a large scale multioperator test. The use of both sound tapes and video tapes together is frequently valuable.

Use/Validity: Sound tapes are now a well used test/evaluation technique. Their use is extremely easy and inexpensive. They have the same advantages as the video tapes in that they are a permanent record of events (audio), they may be repeatedly reviewed, they may be used in hazardous areas, they require no time to process, and can be used with time tags if desired. In addition to this, sound tape recordings negate the need for detailed handwritten notes.

One disadvantage to the use of the recordings is in the quality of the reproduction if a high ambient noise is present near the test data being recorded. Another possible disadvantage is if the test participant becomes self-conscious due to the use of the recorder. This would be more noticeable during an interview.

If the tape recorders are not used, good note taking becomes much more important.

References: Video Tapes, Interview, Direct Continuous Observation.

Alter, F. H., Ground Electronics System for WS-1330, (Minuteman), PSTE Plan, MOP PD 0060, Sylvania Electronic Systems, Minuteman Program Office, Waltham, Mass., March 1964.

Additional information on this technique as compared to other automatic recording techniques may be found in Appendix D.

5.4.3 Video Tapes

Description: This test and evaluation technique is the use of video cameras and related equipment to make video tape recordings for detailed review and evaluation of operator and maintenance personnel tasks.

Actual prototype hardware or extremely sophisticated mockups should be available to justify the use of this technique. Trained test participants must be available for HFE evaluator observation of their appropriate tasks. The camera operator(s) and particularly the HFE evaluator coordinating the video data recording should be reasonably familiar with the test operation being performed. The knowledge of when to use the zoom lens to home in on a particular critical task is important. In order to be sure all the more critical tasks are properly recorded, dry (or test) runs of the test may be advisable. Consultation with all personnel familiar with the anticipated test event is recommended.

The following equipment is necessary to implement this technique:

1) video tape recorder
2) camera (preferably portable)
3) zoom lens
4) monitor
5) lights

Additional lenses, monitors and tripods may be desired depending on the complexity of the test. Sound recording equipment may also be desired. There are a number of easy-to-use video tape recording systems which might be made available to HFE personnel at the test sites and at contractor facilities.

Problems associated with the use of video recordings involve: the logistics of transporting the equipment to the test site; the security of the equipment; permission to record any occurrences in secure areas (e.g., restricted flight line areas); scheduling of the video equipment and a cameraman; and request to perform recording on a possible test interference basis.

Use/Validity: There is little doubt that given the video tapes and proper display equipment, the use of this technique is of notable value. However, the cost effectiveress of the technique must be considered to be dependent upon the complexity of the task needing evaluation. Possible transportation and lighting problems should be considered also before commitment to the use of this technique.

Careful review of tape playbacks can reveal human errors and excessive task times not previously capable of being detected. The application of maintenance crew teamwork may be examined. Improper procedures may be thoroughly evaluated. Improper malfunction determinations may be traced back to the point of the original mistake. Technical publications and training can be methodically evaluated. The adequacy and proper use of tools may be verified.

Depending on how they are used, video tapes may account for less test interference than direct test observation alone. This would be true for an equal amount of test data gathered as a result of a relatively complex test. Once recorded, the data record is permanent and may be presented for use to numerous persons including contractor and customer alike. The tapes may be easily stopped, started and backtracked for repeated observation. Each task may be thoroughly examined step by step. Test sequences that may not be properly recorded may be easily reviewed and retaken.

Further advantages include the fact that observer errors are reduced, the observation can be recorded and observed remotely from what might be a hazardous or congested area. The tapes may have considerable use as training aids. They require no time to process, but motion picture films do. The tape itself is reclaimable; it may be used over and over again for different tests. The record of time tags along with the video is possible.

Disadvantages of the technique are in the requirement for special personnel or training required to use the recording equipment. The initial cost of the equipment is quite high (several thousand dollars for the recorder, camera, zoom lens, monitor, tripod and lights). Slow motion and stop action shots are possible but much more expensive. If necessary, the one alternative technique to use is motion picture film.

References: McDonell Douglas Astronautics has used this technique for several years on aircraft systems such as the F-4E and F-15. The following technical report thoroughly describes the use of this technique on the AN/APW radar, Martin Baker Mark H7 rocket ejection seat, and Rockeye MK20 bomb: Crites, C. D., Video Tape Recording as a Technique for Personnel Subsystem Test and Evaluation, AFHRL-69-18, Air Force System Command, W-PAFB, September 1969.

Additional information on this technique as compared with other automatic recording techniques may be found in Appendix D.

5.4.4 Photography

Description: This technique is perhaps too simple to be considered as such and should be described rather as a HFE test and evaluation tool. It is, very simply, the process of taking photographs of whatever tasks, objects or events that are pertinent to the HFE effort. As in the case of the video records, actual prototype hardware or mockups must be available to justify the use of the tool. HFE test operators must be familiar with the test to know when the critical tasks or events require the visual record.

In addition to the camera, a tripod and special lighting may be required. Flash attachments are easily used. Depending on facility and agency requirements, a photographic pass may be required. The location of the test may restrict the use of cameras. Polaroid type cameras are convenient in that they provide an instant picture for evaluation as to the need for additional pictures. However, the quality of the instant picture cameras tends to be inferior to those which produce the large 8 x 10 shots. The results of the photography generally are appropriate for inclusion in test reports or other HFE test and evaluation reporting forms.

Use/Validity: Naturally, photography is a well used HFE test and evaluation tool. It is easy to use and may be done quickly. The particular advantages gained in using this technique are similar to some of those for the video tapes and motion pictures, e.g., the photograph is a permanent record which may be reviewed, it may be used as a training aid, and decreases observer errors about what really happened. Photographs are used extensively in HFE testing for analysis of anthropometric interface problems.

The obvious disadvantage associated with the use of this T&E tool is in the single frame static picture rather than the dynamic picture created by motion pictures or video tapes. A small problem may be created by the logistics of obtaining the photographic equipment and/or camera personnel and the permission to use the equipment in the test area. Alternatives to photography are the more expensive video tapes or motion pictures or possibly a good fast sketcher assigned the duties of the HFE test observer. In a few instances, a large number of descriptive words written in the test reports may substitute for a photograph of the situation or equipment that they are describing, but these descriptions are seldom completely satisfactory.

References: a) Air Force, Category II System Development Test and Evaluation of the 482L Emergency Mission Support System, PSTE, APGC-TR-65-61, AD 476 172, Volume III, Deputy for Test and Operations, Air Proving Ground Center, Eglin AFB, December 1965.

b) Alter, F. H., Ground Electronic System for WS-1338 (Minuteman), PSTE Plan, MOP PD 0060, Sylvania Electronic Systems, Minuteman Program Office, Waltham, Mass., March 1964.

c) Crites, C. D., Press Camera with Polaroid Back Technique for Personnel Subsystem Test and Evaluation, AFHRL-69-17, Air Force System Command, W-PAFB, September 1969.

d) Majesty, M. S., Human Factors Concepts for Testing Complex Man/Machine Systems, Headquarters Ballistics Systems Division, AFSC, June 1961.

Limited additional information on this tool may be found in Appendix D.

5.4.5 Event Recording

Description: This is a technique or method for recording test situation or event times. The equipment involved in the use of this technique varies in complexity from the stopwatch to complete systems. The more complex event recorder systems might include: an event recorder, battery pack, event control box and a signal cable. The event recorder itself should be capable of recording on several channels; the battery pack is to give portability to the operation; the control box is to actuate the various channels in the recorder, and the signal cable is to electrically tie the control box to the recorder. Other recording systems are provided which combine these units into one easily portable package.

The sequence of events which might occur with the use of this technique may be as follows: HFE personnel who are to observe the particular test first become familiar with the planned test events. They estimate what tasks are more critical and should be

recorded in terms of time performance. If the tasks to be monitored are particularly critical they may even perform a dry run of the test or plan to run multiple replications of the time critical task. The total test may be divided into several functional tasks and each such assignment allocated to a separate channel. Examples of such task functions are reading technical publications, actuating controls, reading displays and making adjustments. The channel controls are easily activated for each of the task functions as they start and stop. It may be necessary to write start labels for each event on each of the channels plotted on the recorder chart paper roll. Figure 5.4-1 shows a sample of this type of annotated record (See Reference (a) this section).

More recently available recording equipment does not require the use of the paper role for a record of events. The test observer simply press combinations of keys to note task functions as they occur. Data entries record in a solid-state memory in a computer program format. The data is later transmitted to the computer by connecting the device via a simple connecting cable. In this manner, computer written reports may be written in minutes (See Reference b). This device includes a space for written notes on an integral note pad.

Another system requires the use of multiple keyboards with ten keys (or pushbuttons) on each keyboard. This system interfaces with a computer through the use of a magnetic tape recorder (See Reference c).

The direct outputs of each of these event recording techniques varies from handwritten notes to complete computer printouts of evaluated data. The eventual outputs are verification of task time data.

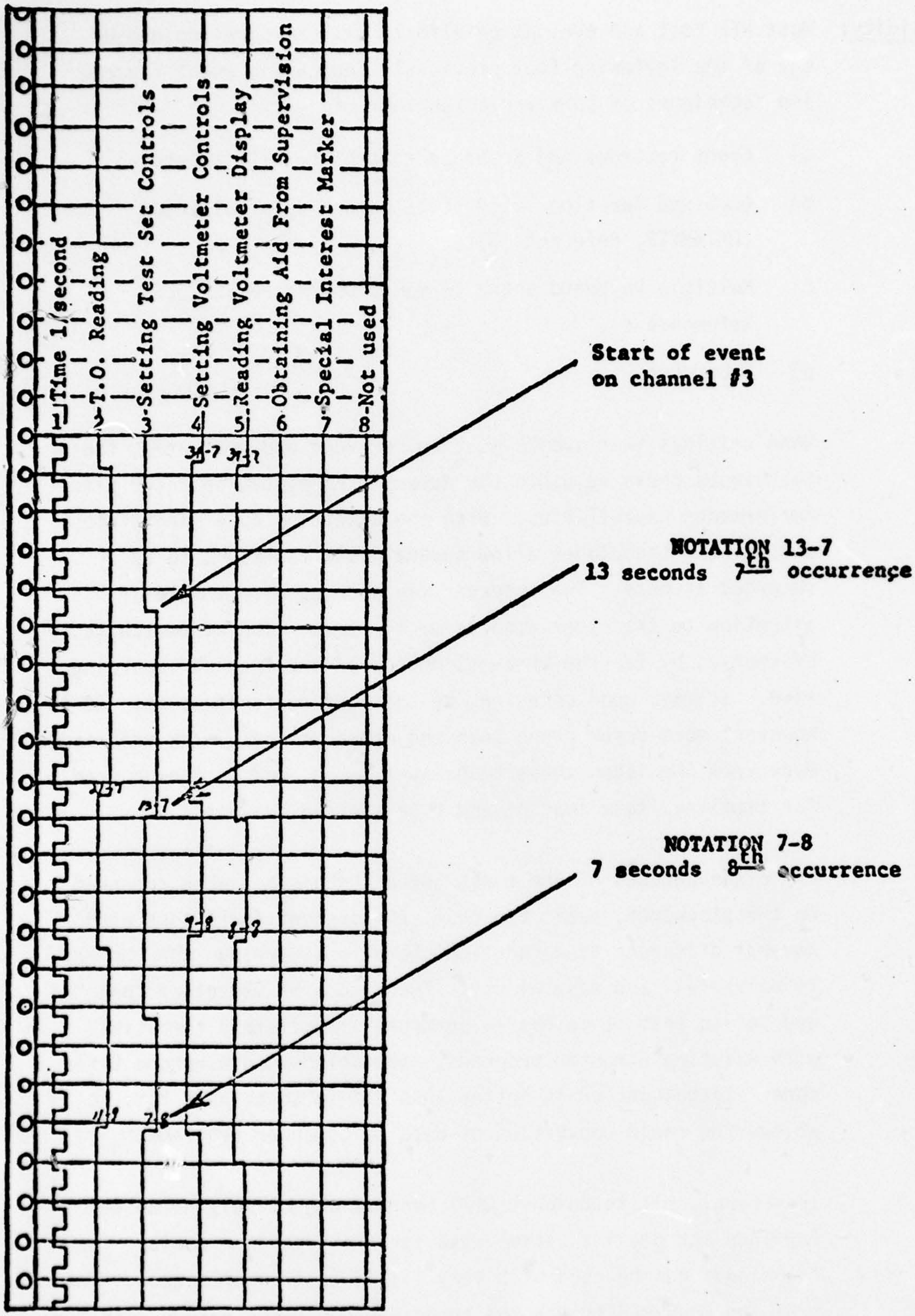

Figure 5.4-1: Sample Annotated Event Record

Use/Validity: Most HFE test and evaluation efforts will require the use of one of the following (but previously indicated) event recording techniques or some variation thereof:

a) Event recorder and separate control box (Reference a).

b) Combined function solid state memory data collector (DATAMYTE, Reference b).

c) Multiple keyboard entry to mag tape records DACOLS, Reference c).

d) Stopwatch.

When critical test events must be recorded and evaluated, these techniques prove valuable for determining system/operator time performance capabilities. With the exception of a single stopwatch these techniques allow several task functions to be recorded at once. The observer may thereby direct more of his attention to the other aspects of the test. The stopwatch is, of course, by far the cheapest method of the four of recording time. It may, upon occasion, be the most cost effective. It is, however, more error prone than the other methods. The recordings made from the later three techniques (a, b, and c) can be used for timeline, task loading and time sharing analysis.

The disadvantages of the first three techniques, when compared to the stopwatch, are: the cost, requirement for a test with several different task function channels occurring simultaneously to be useful, and ease of use. Technique "b" is better than "a" and "c" in that it is easily portable, immediately compatible with existing computer programs, and includes an earphone timer tone. Technique "c" is better than "a" in that, like "b", it allows the rapid conversion of data to computer programs.

In general, all techniques will measure objectively human performance and provide useful data for the test as a whole. The techniques can be used with very little test interference. The training required to use the technique equipment varies with the equipment complexity but is generally uncomplicated. The data

is applicable for time to accomplish tasks, evaluation and optimization of tasks involving team work, and the isolation of specific points that degrade turn-around times, loading times and launch times. The technique may not be used for evaluation per se, but further analysis must be made of the data using other techniques.

References:

a) Crites, C. D., Miniature Event Recording as a Technique for Personnel Subsystem Test and Evaluation, AFHRL-69-16, Air Force System Command, W-PAFB, September 1969.

b) Electro/General Corporation Datamyte Data Collector, Minnetonka, Minnesota 55343.

c) Potempa, K. W., "Data Collection Systems (DACOLS)", A Catalog of Human Factors Techniques for Testing New Systems, AFHRL-TR-68-5, AD 8544821, February 1969.

Additional comparison information on this technique as compared to other automatic recording techniques may be found in Appendix D.

5.4.6 Operational Performance Recording and Evaluation Data System (OPREDS)

Description: OPREDS is a real time data acquisition system which presently is being used to evaluate the Naval Tactical Data System (NTDS) and related command and control system performance. OPREDS consists of two major system components: a computer controlled data acquisition system which collects NTDS and non-NTDS data; and a computerized data management, analysis and information system. OPREDS performs analyses and evaluations of ship systems in two phases:

a) Onboard data recording and preliminary analysis using the Data Collection System (DCS).

b) Data reduction, analysis, storage and retrieval using the OPREDS Data Reduction System on a shore-based IBM System/360 computer.

Together, these subystems permit the reconstruction and performance evaluation of a complete exercise of any duration. Additionally, the onboard analysis feature permits an evaluation

team to conduct preliminary assessments of performance in order to design subsequent exercises and conduct operational tests.

The Data Collection System, the shipboard component of OPREDS, consists of a small, specialized minicomputer and tape transport. These components can acquire and filter all data flowing between the NTDS unit computer and the display consoles. Additionally, data sources external to the NTDS system can be collected and processed using Remote Input Devices (RID). The entire data acquisition and recording process is done in real time and in no way impacts or degrades the system under study nor the performance of personnel associated with its operation. The OPREDS DCS has been carefully designed for this environment and includes the following characteristics:

a) OPREDS does not have to be in immediate proximity to the combat team; thus, the data collection process does not interfere with their functions. In many cases, they are not aware that operations are being monitored.

b) OPREDS does not require any assistance from the combat system's equipment.

c) OPREDS is small, transportable, and can be located in any convenient location.

d) OPREDS' DCS operating programs are firmware. They are indestructible, impervious to interruptions and require virtually no operator intervention.

The OPREDS computer can also be utilized as a stand-alone, general purpose minicomputer when not in the data collection mode.

The OPREDS Data Reduction System (DRS) component consists of a large software system operational on IBM System/360 computers. The DRS decodes the raw data tapes recorded by the onboard system, reconstructs the sequence of events as they occurred

during the exercise, develops track plots and histories, and action listings with English language descriptors of each operator, console action and mode, as well as a variety of statistical analyses.

OPREDS has an alternative configuration allowing for limited onboard, post-exercise analysis. Using the OPREDS DCS, the system can be configured to yield track summaries, relative ranges and bearings between threats and weapons and other key measures.

Because of the unique capability of the DCS to capture all system data, and the generalized management information system construction of the DRS, evaluation and effectiveness measures can be derived from the data with relative ease.

The following data are recorded by the DRS on magnetic tape, or can be determined from displays on the control panel:

a) Identification of each console.

b) Mode of each console.

c) Identification of each quick action button.

d) Identification of each function code.

e) Content of each function code.

f) Time of each action.

g) Link eleven track numbers.

h) Own ship track numbers.

i) Console on which each track displayed.

j) Number of illegal actions per console.

k) Identifier information (Date, time, ship, observer, etc.).

In addition, situational variables must be identified and carefully rated by the observer for interpretation and multiple correlation analyses following the recording. To permit these correlations, each variable will carry a code as a data point for future sorting:

GENERAL:
- Ship Class
- Sea States
- Threat immediacy
- Time on station
- Time on watch
- Time of day

OPERATOR FACTORS:
- Training
- Schools
- On-the-job
- Westpac experience
- Time in service
- Rating
- Previous sleep
- Previous duty

TEAM FACTORS:
- Time together
- Full team
- Degraded team
- New members

SENSOR FACTORS:
- Degraded radar
- Degraded comm.

NTDS FACTORS:
- Dropped program
- Restart program
- Console modes out

JUDGMENTS:
- Operator opinions
- Supervisor opinions
- (Was it tough or easy?)

Results of the data reduction process are summaries of the number of actions and their times for each operator and the CIC team. Examples are: number of tracks handled, separate actions, and submode changes. By subtraction and bracketing, times can be known for events, such as seconds between each action at each console, time spent on each track number processed, and time to firm track, identify track, assign weapons and evaluate threats.

A second output from this module are various types of listings of sequences, such as all of the actions and errors that occur in turn for each track number or combination of track numbers, or the series of actions that occur at each console.

The second program module analyzes the data for statistical information, averages, variability, relationships, and searches for any series of actions that deviate from doctrine or are inefficient for the utilization of the NTDS system. Outputs that result from the analyses are curves, histograms, averages, correlations, exercise reconstructions by continuous listings, by track number, or sets of track numbers and reconstructions in OSD format.

Use/Validity: Prior to development of this system, there was no practical method for use in the operational environment to measure response time and to record each of the operator actions from each NTDS console with the related track numbers, and the number of illegal action errors that are made.

Data obtained from the DRS in a shipboard environment could be used to establish the proficiency of NTDS team members. With this information available, a team of highly proficient operators could be assigned for use during peak load situations (multi-track/high density) and/or hostile engagement phases. With each operator rated according to established performance standards, on-the-job training requirements for individual operators would be clearly defined. Concerted training could be directed to those operators that are below the performance standards.

Until the development of the DRS, effectiveness of training provided to NTDS operator personnel was based primarily on judgments made by instructors, and to a limited degree on quantitative data extracted from various computerized data reduction programs. The installation of the DRS at NTDS training activities, such as the Fleet Anti-Air Warfare Training Centers, could be used to measure NTDS console operator performance during the period of time that the student is being provided instruction. Using the DRS, operator performance can be measured and a comparison made between fleet performance standards and training performance standards achieved during the training period.

From the above analyses and outputs, evaluation will be made as to the level and efficiency of performance. The source of major delays can be examined as to who caused them, what they were, who was involved, how they differ from week-to-week, watch-to-watch and supervisor-to-supervisor.

When used with UYK-7 on shipboard, immediate evaluations of team performance is possible. By rating operators to pre-established standards, and from day-to-day monitoring, their operational readiness can be evaluated for the establishment of a highly proficient "Critical Situation" team.

In the last two years, OPREDS has demonstrated its effectiveness in evaluating NTDS performance in a variety of shipboard environments. These ships include the USS Independence (CV-62), USS England (DLG-21), USS Towers (DDG-9, JPTDS ship), the Fleet Anti-Air Warfare Training Center (FAAWTCPAC), the NELC ASDEC Test Site and several other DLGs conducting training exercises with the dockside T1 van. OPREDS can interface with all current NTDS systems and consoles. It has been used with SYA-1, SYA-4, UYA-4, and OJ-194 consoles on both NTDS and JPTDS (JEEPS) equipped ships.

References: The Operational Performance Recording and Evaluation Data System (OPREDS), Barten and Associates, Santa Monica, California, June 1975.

The DRS was developed by Jakus Associates (E. B. Morrison and J. R. Harris) and the OPREDS was designed by Barten & Associates (B&A) under contract to the Naval Electronics Laboratory Center (NELC), San Diego, California. Additional information on this technique as compared to other automatic recording techniques may be found in Appendix D.

5.4.7 Secondary Task Monitoring

Description: For the purpose of determining crew workload, test participants are given both operational tasks and secondary tasks to perform. The secondary tasks may or may not be meaningless in relation to the rest of the test set up. They are, however, in no way necessary to the operational tasks being tested. The secondary tasks are performed with prototype hardware or hot mockups on special equipment that is instrumented through hardwire or telemetry to record crew performance. The participant is instructed to perform the secondary tasks when not required to perform the operational tasks. The time taken to perform the secondary tasks is recorded and subtracted from the total time available. In this manner, the crew workload required to perform the operational tasks is implied on the basis of the measured time (or effort) not spent doing those same operational tasks.

Use/Validity: This is a useful technique to measure crew workload particularly when it is not feasible to monitor directly the operational performance parameters. Because workload can be quantitatively measured in this case, it can be more accurate than many other workload evaluation techniques. The cost and effort to implement this technique is relatively high as compared to several other HFE T&E techniques if the secondary task data is recorded automatically. However, the cost is inherently lower than monitoring operator performance on each of the operational controls (and, if possible, displays).

There are two basically different types of secondary task monitoring. The first type uses secondary tasks that are completely unrelated to the system operational tasks. These are make-work tasks. The second type is more sophisticated in that the secondary tasks are essentially the same as the required operational tasks. Test participants seem to have more motivation to do the more real secondary tasks rather than the make-work tasks.

References: Knowles, W. B., "Operator Loading Tasks", Human Factors, Vol. 5, 1963.

Potempa, K. W., A Catalog of Human Factors Techniques for Testing New Systems, AFHRL-TR-68-5, AD 854 482L, February 1969.

Rolfe, J. M., "The Secondary Task as a Measure of Mental Load", Measurement of Man at Work, Taylor and Francis, London, 1971.

Additional data on this technique as compared with other techniques may be found in Appendix D.

5.5 Physiological

5.5.1 Physiological Instrumentation

Description: The process of measuring test participant physiological data is generally quite rigorous. In addition to all of the set up procedures required for the test itself, it requires several important tasks that must be performed just for the physiological instrumentation.

Physiological measurement requires more commitment from the test participants. The purpose of the instrumentation may be to monitor physiological parameters to insure that the participant remains in a safe range of performance. The implication of this is that there is a possible unsafe range of performance and therefore more commitment required on the part of the test participant. Even if this is not the case, the encumbrances of the test sensors on the participant are generally somewhat annoying.

Trained medical personnel must approve the test. Generally, they should perform the test set up of the instrumentation system. This would involve the attachment of the sensors to the participants. Care must be taken to place the sensors in a manner to minimize their effect on the total test. Medical personnel must also be present during the test if any participant risk is involved.

Electronics technicians may also be required to adjust the test instruments.

In addition to the individual parameter sensors located on the participant, wire leads must be provided. Attached to the leads would be the appropriate transmitters (if telemetered), receivers and/or amplifiers. Instruments for displaying each of parameter values and chart recorders will also be required.

Parameters that might be monitored are as follows:

a) heart rate, blood pressure

b) respiration rate, volume

c) galvanic skin response (GSR)

d) electroencephalograph (EEG)

e) electrocardiograph (EKG)

f) body temperature

g) body movement.

Upon completion of the test, medical personnel are required for analysis and evaluation of the resulting test physiological data.

Use/Validity: Physiological measurement is performed much more for research testing than for operational or field type testing. It is also used when there is a possibility of risk involved, for example, centrifuge runs. Physiological testing is seldom intended to measure total system performance, let alone the more normally monitored operator performance parameters of time and errors.

The cost to perform this type of testing is relatively high and the effort involved by HFE, medical and technical personnel is considerable. Because of the nature of the test itself, which would require the use of physiological instrumentation for safety, the testing must be considered to be performed on an interference basis. When physiological monitoring is really needed, there is no substitute technique that may be used to obtain the necessary data. The only alternative of constantly stopping the test to take time out for the required measurements is unacceptable. By use of radio transmitters, the technique may be monitored remotely away from the test area. The most notable use of this technique has been in manned space programs, i.e., Skylab, Apollo, Gemini and Mercury.

References:

a) Zonjer, F. H., "The Contribution of Work Physiology to the Evaluation of Man-Machine Systems," Measurement of Man at Work, Taylor and Francis, London, 1971.

b) Brown, C. C., and Saucer, R. T., Electronic Instrumentation for the Behavioral Sciences, C. C. Thomas, Springfield, Illinois, 1958.

c) Glassner, H. F., and Peters, G. A., "Bio-Electronic Analysis of Performance", PAC Engineering Paper No. 897, AD 235 969, Equipment and Safety Research Section, Douglas Aircraft Co., Inc., March 1960.

d) Jacobs, E. P., Second Interim Report, Test Instrumentation for Pilots in High Performance Aircraft to Evaluate Cockpit Environments and Personnel Physiological Equipment, Report No. ST35-43R-63, AD 480 526, Naval Air Test Center, September 1963. Lindsey, J. F., et al., Proposed Pilot Model for Combat Effectiveness Testing, PGN Document 62-7, Deputy for Bioastronautics, Air Proving Ground Center, Eglin AFB, August 1962.

Additional information on this technique as compared with others may be found in Appendix D.

5.5.2 Physical Measurement

Description: This technique is the process of measuring what the test participants can do in terms of their physical performance or what they are doing in terms of physical and cognitive performance. Three different types of physical measurement are presented in this section. The first, anthropometry, deals with potential test participant physical performance. The other two, oculometry and voice monitoring, pertain to measurement of the participants' physical and cognitive processes.

Anthropometry. Anthropometric measurements may be made of each of the test subjects to be used in a hardware prototype or mockup test. These measurements are taken on the assumption that the test will indicate various areas of work space or work access verification. If problems are indicated, rather than designs verified, then detailed measurements are taken as to exactly how much of a work space problem exists. If much of the test is to hinge on the ability of the test participants to fit the equipment (e.g., cockpit egress), the subjects may be specially screened and chosen to fit the worst case (larger) population percentiles (95th or 98th percentile). If a subject with 98th percentile buttock-knee length and 98th percentile shoulder breadth can successfully egress with the given cockpit dimensions, then it may be assumed that most pilots will be able to do the same at least in terms of egress space.

Oculometry. This is the technique of measuring the test participant's eye movement while he is seated at (in) a mockup or prototype hardware of the system being tested. The oculometer is used to view the participant's eye movement in terms of deflection rate and amount. The instrument and associated equipment is capable of recording the links between controls and dipslays, the dwell times on each, the total number of eye contacts, and the probability of next contact. The oculometer performance is at a half degree at 30 inches from the eye within an envelope 30° up,

10° down, and 60° horizontal. Once this data is recorded, panel layout adequacy is verified by the quantity, location and rate of eye movements.

Voice Monitoring. This technique is performed as a means of psychological stress evaluation. By the use of sophisticated voice monitoring equipment, similar to that being used for lie detection, the voice is analyzed to determine stress. The stress indicates test situations where the participant is having problems or is close to the point of having problems. The voice stress analysis equipment requires operation by trained evaluators. These evaluators should be familiar with the system test objectives in order to be better able to analyze test data and to recommend problem solutions.

Physical measurements may also include participant muscular strength, body weight, limb coordination, visual and auditory acuity, and kinesthetic response.

Use/Validity: Anthropometry. It is relatively easy to measure test participants to determine their anthropometric measurements. The fact that these subjects either did or did not fit the particular mockup or prototype is also easy to note and record. The difficulty in the use of this technique is if and when particular anthropometric dimensions are required as test subjects. It is very difficult for HFE observers to go out and find particular anthropometric dimensional subjects, particularly for combinations of measurements and for the extremes of the population (e.g., greater than 90th percentile and less than 10th percentile).

The real value in using anthropometric measurements is in the knowledge of how close the design, as represented by the mockup or prototype, comes to the specified user anthropometry. The disadvantage is the effort in finding subjects who properly represent the required population. If this technique is not used and work space clearances are critical to the test conduct, the HFE observer runs a high risk in only guessing the anthropometric characteristics of the test participants.

Oculometry. The oculometer technique is relatively complex and expensive to use. It cannot be run on a non-interference basis. It requires trained HFE observers to use. The use of the technique is still somewhat experimental. The major advantage in the use of the technique is that it is the ideal way to perform or verify cockpit or console panel link analysis data. If not used, questionnaires or interviews may be used to determine subject reaction to panel layout adequacy.

Voice Monitoring. The use of voice monitoring is both experimental and controversial. Like the oculometer, it is a complex technique. It requires trained evaluators and special equipment and is therefore expensive. Interpretation of the test participant voice qualities is variable. On the plus side, the technique may reveal problems that no other technique could uncover. The only alternatives to its use are interviews and questionnaires to try and dig out stressful test situations. This technique has been used in pilot evaluation during aircraft carrier night landings.

References: There are several anthropometry references including the techniques of CAPE, CAR, CGE, Environmental and Perforamnce Measuring Equipment, and G-2/G-5 Anthropometers. Text book data may also be found in numerous publications including Van Cott, H. P., and Kinkade, R. G., Human Engineering Guide to Equipment Design, sponsored by Joint Army-Navy-Air Force Steering Committee, U.S. Government Printing OFfice, 1972. MIL-STD-1472B, Human Engineering Design Criteria for Military Systems, Equipment and Facilities, also includes a large amount of anthropometric data.

Additional oculometry data may be found in NASA reports NASA-CR-149951 by Honeywell (Boston) and NASA-TM-X-3344 by Jim Wise. A recent Honeywell report is titled An Oculometer Now Unobtrusively Reveals What You Are Looking At.

The subject of speech intonations is covered in a report by Luk'yanov, A. N., and Frolov, M. V., Signals of Human Operator State, NASA-TT-F-609, 1969.

5.6 Simulation

5.6.1 Cockpit Geometry Evaluation (CGE)

Description: The Cockpit Geometry Evaluation (CGE) Program is an experimental development partially funded by the Joint Army - Navy Aircraft Instrumentation Research (JANAIR) Program Working Group to develop an improved method of evaluating the physical compatibility of crewmen with specified crew stations. The heart of the program is a computerized mathematical man-model (BOEMAN). The CGE Computer Program System (CGECPS) serves as the basic integrated tool to store required anthropological and geometric data, make computations to simulate typical crew movements during the performance of tasks, check and correct for visual and physical interference, and output related information. Crew station compliance with selected military standard and specification is also performed.

Using the baseline Computer Program System developed in the first phase of the program, the second phase of this project added a three-dimensional "human" form to the first phase stick man. Also provided were leg movement capability and a crew station component description sufficient to enable a generalized physical interference detection procedure to function effectively. The 23 pin-joint link-man received three-dimensional body segments surrounding his links. The length and mass of the segments remained variable, so that a crewman with any link length can be approximated. Currently, the breadth and width of the body segments remain fixed at 50% values since they influence crew operability significantly less than link lengths and such a technique helps standardize evaluation results. A mathematical optimization routine is used to simulate movement by the man-model in a given crew station configuration.

A later phase of this project provided: increased efficiency in generating man-model positions, variable joint angles to more closely resemble human limits of bend on the links, physical

restraint simulation of lap belts and shoulder harnesses, a preliminary physical interference avoidance procedure to eliminate hand and foot interferences during the task, examination of compliance checks with MIL-STDs and SPECs, and evaluation of an existing aircraft cockpit for physical compatibility problems.

The latest phase of this project provides: expansion of the MIL-STD and MIL-SPEC requirements compliance checking program, analysis of additional applications, improvement and scope reductions of the Computer Program System, continued and expanded crew station evaluation, continued man-model improvements in accuracy and speed, and continued refinements in storage, timing and the capabilities of the CGECPS.

Use/Validity: The CGECPS may be used to evaluate a crew station with a given sized man-model (BOEMAN) performing a task sequence. Each task may be pre-checked for reach envelope compatibility. Straight line hand and foot trajectories may be initially prescribed to perform the task. If there are interferences with any trajectory, a new segmented linear trajectory can be calculated to try to avoid the interference. Joint and body segment vertex locations and link and body segment orientations are synthesized at various positions of each task. Then the resulting positions are tested for the occurrence of physical interference and the final position of each task is additionally checked for visual interference. Finally, numerical performance data used for further comparison purposes for different crew station designs or different sized individuals or similar tasks are calculated.

The capability of storing and retrieving anthropological, geometric and flight mission data is built into the system. Successful running of the Cockpit Geometry Evaluation Computer Program System has been accomplished, validations have been performed against human movement criteria, and the evaluation of the A-7E aircraft for 52 different tasks has been made for 3rd, 5th, 95th and 98th

percentile BOEMAN. The A-7E aircraft shows that significant physical compatibility problems that exist in a real aircraft can be discovered by this evaluation method and that they should be able to be detected beginning with the conceptual phases of design.

Further improvements to CGE are required. Improvements to the computer time required to synthesize task performance and scrutinize a greater number of tasks are still necessary, if the tool is to be used with maximum utility. Actual and total evaluation of proposed crew stations with unknown physical compatibility problems may next be made to validate and improve the elements of the system, as well as begin to provide the best of several designs and/or indicate problems with a given design much sooner.

CGE is more of a design technique than a test and evaluation technique. It may be used at any time after the DSARC I decision date but it is best used prior to formal test and evaluation. The advantages to using CGE may be summarized as follows: the technique may be used for dynamic problems, a large data bank is available to draw on, the program will optimize the problem solution, any percentiles of the given population may be tested, and the anthropometric model is extremely sophisticated.

The disadvantages associated with the use of CGE are that: it operates in batch mode only; compared with other computer simulations, it is complex; it requires special training to understand and use; and it is costly - especially when compared to an experienced HF engineer's judgment of similar situations.

References:

a) Katz, R., Cockpit Geometry Evaluation, Phase II Final Report, Volume III: Computer Program System, D162-1012703, The Boeing Co., JANAIR Report 720402, November 1971.

b) Whitmore, D. C., and Parks, D. L., Computer Aided Function Allocation Evaluation System, Phase IV, Vol. 1, D180-18433-1, Boeing Aerospace Company, December 1974.

Additional data on anthropometric techniques, including CAR and CAPE, may be found in other sections of this guide. Appendix D contains evaluation sheets on this technique as well as others.

5.6.2 Crewstation Assessment of Reach (CAR)

Description: The CAR Model establishes the actual percentage of naval aviators that can be accommodated in the critical areas of a given crewstation geometric configuration. The model examines hand and leg control positions, seat movement to establish over-the-nose vision, and head clearance for a representative sample of the naval aviator population and determines the following:

a) The percentage of naval aviators that are able to position themselves at the horizontal plane of the Design Eye Point (DEP) within given limits of horizontal and vertical seat adjustment.

b) The percentage of aviators that have a specified minimum "above the head" clearance while positioned as close to the plane of the DEP as possible.

c) The percentage of aviators that are capable of reaching the primary hand and leg controls in a crewstation while positioned as close to the DEP as possible.

d) The amount of relocation required on specific controls to accommodate a specified percentage of aviators.

Reach analyses can be performed under both restrained and unrestrained conditions. With the shoulder harness locked, the model will check for maximum reach without straining against the harness and for maximum reach while straining against the harness. The shoulder harness is unlocked for the maximum reach check in the unrestrained condition.

The CAR Model operates on the CDC 6600 computer under the KRONOS 2.1 Time Sharing System. The model is designed for interactive use. It coaches and prompts the user in the use of the model.

CAR consists of two stand alone programs: (a) a Monte Carlo Simulation Module which is used to convert anthropometric data into link lengths for a man model, and (b) a Crewstation Analysis Module which is used to evaluate candidate crewstation configurations.

Use/Validity: The CAR man-model objective is to develop an expedient, efficient, and easily improvable method of assessing the realistic reach capability of United States Naval flying personnel in any given upright seated crew workstation.

An analysis of the assumed hypothetical "constant percentile" aviators versus the actual aviator population indicated the need to design and evaluate crewstations according to the actual measurements of the intended flying personnel. The CAR evaluative method is sufficiently rapid to minimize expenditures and is convenient enough to ensure that the HFE analyst will employ the technique.

The technique is better used for system design than test and evaluation. The CAR man-model makes use of several preceding man-model efforts in that:

a) A simplified link man-model is used. Such a concept proved highly amenable to efficient computer programming techniques. Just as important, the concept also proves to be a valid representation of the human body when one desires to synthesize seated operator reach capability.

b) The model has joint angular limits modeling those of the seated operator.

c) The reach zone concepts of MIL-STD-1333 are retained.

The interactive use of the model is enhanced by the program design which coaches and prompts the user in the details of the CAR program procedures. This feature significantly reduces user training requirements. Persons with little or no programming experience may use the model.

CAR has been successfully used on the F-18 (reach problem) and the A-7 aircraft.

One disadvantage associated with the CAR model technique is that it is not a dynamic model. Only static problems may be evaluated. CAR does not recommend possible solutions, it only answers specific problems. It cannot optimize a solution to a given problem. Several less significant anthropometric parameters and relationships are not included in the model.

If CAR is not available for use, CGE or engineering drawing geometric analysis may be used in its place. Mockups or prototype hardware in combination with selected extreme percentile subjects may be effectively used in place of this technique.

References: Edwards, R. E., et al., Crewstation Assessment of Reach, User's Manual, D180-19321-1, Boeing Aerospace Company, (NASC 340F), April 1976.

This work was developed for the Naval Air Systems Command and monitored by the Naval Air Development Center.

A comparison of this technique with others, including CGE, may be found in Appendix D.

5.6.3 Computer Accommodated Percentage Evaluation (CAPE)

Description: CAPE is a Monte Carlo computer model for generating representative pilot anthropometric features (including links) and comparing these date with an adjustable work-space model so that the population accommodated by the workspace can be estimated and maximized.

The computerized accommodated percentage evaluation (CAPE) model has two options: exclusion demonstration and cockpit analysis. Each option, and its underlying model with components, is described in summary form below. More detailed descriptions of model options, their components and the total CAPE model are contained in the reference.

An exclusion demonstration determines what percentage of a potential population is excluded from a workspace design with respect to each anthropometric feature entered into the program. This CAPE option may be considered to be composed of two components, an exclusion limits component and a Monte Carlo sample generator.

The Exclusion Limits Component provides for the entry, storage and utilization of user-provided standard score limits of anthropometric variables required for exclusion studies. For each variable involved in an inclusion demonstration analysis, high cutoff and low cutoff values must be input by the user. This component of the analysis provides for the sequential testing, element by element, of Monte Carlo-generated standard score vectors to determine if the vectors are within the limits set by the high and low standard score boundaries (populations of standard scores have means of zero and standard deviations of one.) Rejection of any component test is defined as non-accommodation of that (sample subject) feature vector.

The Monte Carlo Sample Generator Component generates quasi-random vectors of standard scores that match a user-provided correlation or correlation square-root matrix. It is based on a method which generates standard score feature vectors with a given correlation matrix. Conformable vectors of quasi-random normal variants generated by a subroutine are premultiplied by the square root of the desired correlation matrix to produce a quasi-random standard score vector. This vector can be viewed as a sample subject feature vector whose elements have been converted into standard scores.

The cockpit analysis determines the percentage of a population that will be excluded from a cockpit design based on the geometric parameters of the workspace. The cockpit analysis option of the CAPE program can be thought of as being composed of four components: a) a pilot link system component, b) a sample pilot generator component, c) a component characterizing a seat-cockpit layout, and d) a cockpit testing component. The pilot link system is an abstraction of a pilot's anthropometry. The sample pilot generator provides sets of pilot link values suitable for input in the pilot link model. When the compatibility of a geometry is desired, these values are entered as the mean, and the generator provides only this one sample. However,when a pilot accommodation analysis is desired, this generator provides quasi-random samples from a multi-variate normal population.

The program uses batch FORTRAN with a SUPER FORTRAN option.

Use/Validity: Although CAPE has been designed for use in cockpit analysis, design and evaluation, it may be used to maximize the population of personnel to be accommodated in any workspace.

Aircraft cockpits and many other workspaces traditionally have been designed without knowledge of the proportion of the user population that is accommodated with safety and full capability. In aircraft cockpit design, for example, designers have been directed to develop cockpits that accommodated 5th through 95th percentile operators. However, crew systems designers are designing for the 5th through 95th percentile population only one dimension at a time. The combination of all the necessary dimensions that make up a workspace design limit the operators to a much smaller actual range than 5th through 95th percentile. It has been shown that more than 52 percent of the 1964 population of naval aviators would be excluded when 5th and 95th percentile critical limits are imposed. When the Navy specified 3rd and 98th percentile values are used, over 32 percent would be excluded. This problem has led to the development of CAPE.

One disadvantage in using this technique for workspace evaluation is that it requires special training to use, both from the standpoint of the user and the programmer. The cost of computer use may or may not be significant depending on several variables. It is interesting to note that design criteria do not exist that will allow the design of man-machine interfaces to accommodate 90 percent of the population. MIL-STD-1472 criteria will allow the accommodation of 90 percent of the population for only one dimension (or parameter) at a time. It would be extremely difficult, if not impossible, to develop these anthropometric criteria for all workspace design situations.

If this technique is not used, specially selected subjects whose anthropometric data approach the percentile extremes may be used to test the workspace design. However, these subjects are extremely difficult to find and they are not a satisfactory means of determining just what user population is actually accommmodated. Another method is to measure all significant workstation dimensions that relate to critical anthropometry and compare them to the MIL-STD-1472 design criteria. The effect of this would be to waive the presumed design requirement to provide for 90 percent of the user population.

Although CAPE may be used as an evaluation technique, it should be used prior to formal test and evaluation. It is more properly considered a design technique.

Reference: Bittner, A. C., Computerized Accommodated Percentage Evaluation (CAPE) Model for Cockpit Analysis and Other Exclusion Studies, TP-75-49/TIP-03, System Integration Division, Pacific Missile Test Center, Point Mugu, California, December 1975.

Additional information on this technique as compared with other automatic simulation techniques may be found in Appendix D.

5.6.4 Field of View Evaluation Apparatus (FOVEA)

Description: FOVEA is a technique used to test and evaluate the pilot's field of view from the cockpit eye reference point. It is designed to plot the actual field of view rather than the field of view as represented by photographs and distorted reference grids.

The technique requires the procurement of certain expensive test equipment such as a video camera, video recorder, a small computer, and plotter (or high quality graphics prints). Remote maneuvering equipment is also required to move the camera and to provide an X-Y signal input to the computer. The remote equipment consists of a monitor to view the camera video; a joy stick, force stick or trackball to control the camera line of sight; and the servos to actually position the camera where desired.

The test set-up requires the placement of the video camera in the cockpit mockup or prototype on the seat pan at a set distance from it which would be equivalent to the location of the eye reference point. The camera is manipulated with the hand controller to trace the outline of the canopy or windscreen windows. The remote camera operator (HFE observer) knows where to place the camera by viewing the center spot on the monitor unit. At the same time that the camera moves, similar signals from the servo driving system are sent to the computer which, in turn, plots out the outline of the pilot's view from the cockpit or appropriate peripheral plotting equipment.

The plotted view from the eye reference point may then be compared with the appropriate specification requirement.

Use/Validity: FOVEA is an experimental technique. The primary advantage in use of FOVEA is that it provides a means of measuring the vision envelopes and angular locations of objects. It records this data both digitally and graphically and in a manner compatible with specification criteria for comparison and evaluation. It is not designed to address the adequacy of visual fields or locations of objects

in terms of operational factors but merely to produce objectively measured records of what exists in a crew station. Additional disadvantages associated with FOVEA are the cost of the test equipment and setup.

There are several alternatives to this technique that may be used. It is possible to convert engineering drawings into extremely accurate comparative vision envelope plots. It is very easy to take photographs (with the proper lens) and to compare these with spec requirements. Either linear or distorted grids may be added for purpose of comparison. Utilizing a surveyor's transit and a hand held transit vision plots of the pilot's visual envelope have been successfully accomplished. Interviews and questionnaires are also good sources of subjective data as to adequacy of cockpit field of view.

<u>References</u>: Weaver, A. J., <u>Field of View Evaluation Apparatus, Survey, and Analysis; First Interim Report</u>, SY-13R-76, Naval Air Test Center, Patuxent River, October 1975.

Other techniques should also be reviewed for comparison:

Terrain Visibility Definition
Interviews/Questionnaires
Photographs

A comparison of these techniques with FOVEA may be found in Appendix D.

5.6.5 Online Interactive Simulation

<u>Description</u>: Previous HFE T&E technique sections have described techniques which rely heavily on prototype hardware or mockups. Also included in this guide are several techniques which do not use either mockups or hardware, but are instead computer program simulations of both the operator and equipment in the man/machine interface (e.g., CGE, CAR, CAPE). The general technique described in this section pertains to the use of real time computer program simulations and actual test participant operators. Like other simulations, online interactive programs are used to evaluate and demonstrate the application of specific procedures

and equipment to specific operations. It is often difficult to make a sharp distinction between some computer simulation set-ups and functional mockups. The emphasis in the functional mockup is on an accurate representation of spatial dimensions and arrangements.

The most important requirement of an online interactive simulation is that it be an accurate representation of some portion of the proposed system. Critical variables in the proposed system should be properly duplicated in the simulation. In some cases, simulators must actually provide deliberate distortions of certain parameters in order to yield operator responses that will be valid for the real world. The use of distortions is risky but often necessary to compensate for some parameter that cannot be provided for properly.

Online interactive simulation presumes the use of a sophisticated computer and software. Test participant consoles must also be provided in a manner similar to the system consoles being simulated. The preparation of test participant operator procedures is a first step toward the complex job of constructing the real time interactive software. Online operation requires the construction of numerous operator commands in response to numerous displays and display formats. Operator and system performance outputs must also be provided for in terms of lists and time plots of events versus actions, errors, and reaction times.

Use/Validity: The reason for using online simulation is because of the ability to find out what might occur: to manipulate, to study, and to measure the model instead of the real world.

There are several advantages to using online simulation as compared to other methods of T&E:

a) Simulators are frequently cheaper, faster and easier to construct than the systems or prototype hardware they simulate.

b) Simulators can be instrumented to collect data that would be difficult or impossible to obtain from real systems and the data may be quickly reduced to usable form.

c) Simulators are extremely useful as training aids.

d) Simulators are easier to manipulate than the systems they represent.

e) Simulators may be used to perform tasks that would otherwise be hazardous to the test participants (e.g., crash landings).

f) Once the simulation program has been provided, alternative procedures or tactics may be easily manipulated.

g) A record of data may be kept for later playback.

The disadvantages in the use of online simulation as compared with other T&E techniques are as follows:

a) Simulation tends to invite overgeneralization.

b) Simulations may be wrong because of incorrect relationships that have been made to hold between variables, or assumed constraints may be in error.

c) Simulators may add ingredients of their own that will not be found in the real world system.

d) Simulators, in general, are very expensive.

The time to use online simulation is generally before the construction of the hardware (and software) that it is to simulate. If this is not done, there is little point in the expenditure of the time and effort for the simulation.

There are essentially two alternatives to the use of online interactive simulation. One simulation technique is the use of man model programs such as the CGE, CAR and CAPE models previously mentioned. The other alternative is the use of all the T&E techniques which utilize the direct or indirect data obtained from the actual prototype system hardware.

References: Van Cott, H. P., and Kinkade, R. G., Human Engineering Guide to Equipment Design, Joint Army-Navy-Air Force Steering Committee, AIR, Washington, D. C., 1972.

The OPREDS (Reference Section 5.4.6) is in several ways a similar technique; however, OPREDS is used with actual hardware. Additional information on the online interactive technique as compared with other automatic techniques may be found in Appendix D.

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APPENDIX A: LIST OF PERSONNEL SURVEYED

One of the first tasks in the preparation of this guide was to visit various Navy labs and centers. Knowledgeable personnel were questioned in regard to their HFE T&E experience, problems, and needs. The Appendix D T&E worksheets are based to certain extent on the results of this survey. The following is a list of those contacted during the survey visits.

NADC - Warminster
- Dr. L. Hitchcock
- LCDR N. Lane
- D. E. Murry

TECOM/HEL - Aberdeen
- J. Perkins
- J. Miles
- Dr. J. Getty

NATC - Patuxent River
- A. Weaver
- Dr. S. G. Schiflett
- R. M. Walchli

NAVAIR - Jefferson Plaza
- J. C. Hemingway
- S. Miller

CNO - Pentagon
- Dr. R. Smith

ONR - Arlington
- Dr. M. Tolcott
- G. S. Malecki

OPTEVFOR - Norfolk
- T. P. Enderwick

NTEC - Orlando
- LCDR J. Funaro
- Lt. R. E. Perryman
- W. B. Boney
- R. G. Bird

OPTEVFOR - North Island
- Dr. R. Rhea
- LCDR W. F. Moroney
- Lt. W. R. Helm

NELC - San Diego
- R. Coburn
- LCDR W. F. Moroney
- Lt. W. Helm

NPRDC - San Diego
- Dr. D. Meister
- R. Harris
- LCDR W. F. Moroney
- Lt. W. Helm

APPENDIX B: DEFINITIONS/ACRONYMS

AFHRL	Air Force Human Resources Laboratory
AWACS	Airborne Warning and Control System
BOEMAN	Computerized Math Man-Model
CAPE	Computer Accommodated Percentage Evaluation
CAR	Crewstation Assessment of Reach
CGE	Cockpit Geometry Evaluation
CIC	Combat Information Center
CPS	Computer Program System
CTE	Contractor Technical Evaluation
DA	Developing Agency
DACOLS	Data Collection System
DCS	Data Collection System
DEP	Design Eye Point
DoD	Department of Defense
DRS	Data Reduction System
DSARC	Defense System Acquisition Review Council
DT&E	Development Test and Evaluation
EEG	Electroencephalograph
FLAG	Feedback Loop Action Generation
FOT&E	Follow-on Operational Test and Evaluation
FDI	Functional Description Inventory
FOVEA	Field of View Evaluation Apparatus
EKG	Electrocardiograph
GPTP	General Purpose Test Planning
GSR	Galvanic Skin Response
HE	Human Engineering
HEDGE	Human Engineering Data Guide for Evaluation
HF	Human Factors
HFE	Human Factors Engineering
HFTEMAN	Human Factors Test and Evaluation Manual
HPR	Human Performance Reliability
ILS	Integrated Logistics Support
IOT&E	Initial Operational Test and Evaluation
JANAIR	Joint Army Navy Aircraft Instrumentation Research
LED	Light Emitting Diodes

APPENDIX B: DEFINITIONS/ACRONYMS (cont.)

NAVMAT	Chief of Navy Material
NTDS	Naval Tactical Data System
NTE	Navy Technical Evaluation
OPEVAL	Operational Evaluation
OPNAV	Chief of Naval Operations
OPREDS	Operational Performance Recording and Evaluation Data System
OT&E	Operational Test and Evaluation
PAARS	Personnel Activity Analysis Radio System
PAT&E	Production Acceptance Test and Evaluation
PSTE	Personnel Subsystem Test and Evaluation
RFP	Request for Proposal
RID	Remote Input Devices
SOW	Statement of Work
SECNAV	Secretary of Navy
T&E	Test and Evaluation
TECHEVAL	Technical Evaluation
TEMP	Test and Evaluation Master Plan

APPENDIX C: T&E SECTIONS OF MIL-H-46855

3.2.4 Human Engineering in Test and Evaluation - The contractor shall establish and conduct a test and evaluation program to: (1) assure fulfillment of applicable requirements herein; (2) demonstrate conformance of system, equipment and facility design to human engineering design criteria; (3) confirm compliance with performance reqirements where man is a performance determinant; (4) secure quantitative measures of system performance which are a function of man-machine interaction; and (5) determine whether undesirable design or procedural features have been introduced. (The fact that these functions may occur at various stages in system or equipment development shall not preclude final human engineering verification of the complete system. Both operator and maintenance tasks shall be performed as described in approved test plans during the final system test.)

3.2.4.1 Planning - Human engineering testing shall be incorporated into the test and evaluation program and shall be integrated into engineering design tests, contractor demonstrations, R&E acceptance tests and other major development tests. Compliance with human engineering requirements shall be tested as early as possible. Human engineering findings from early testing shall be used in planning and conducting later tests.

3.2.4.2 Implementation - The human engineering test and evaluation program, contained in approved test plans, shall be implemented by the contractor. Test documentation (e.g., checklists, data sheets, questionnaires, schedules, operating procedures, test procedures) shall be available at the test site. Human engineering portions of all tests shall include, where applicable, the following:

a. A simulation (or actual conduct where possible) of mission or work cycle.

b. Tests in which human participation is critical with respect to speed, accuracy, reliability or cost.

c. A representative sample of non-critical scheduled and unscheduled maintenance tasks.

d. Proposed job aids.

e. Utilization of personnel who are representative of the range of the intended military user population in terms of skills, size and strength and wearing suitable military garments and equipment which are appropriate to the tasks, and approved by the procuring activity.

f. Collection of task performance data.

g. Identification of discrepancies between required and obtained task performance.

h. Criteria for the acceptable performance of the test.

3.2.4.3 Failure Analysis - All failures occuring during, or as a result of, test and evaluation shall be subjected to a human engineering review to differentiate between failures due to equipment alone, man-equipment incompatibilities and those due to human error. The procuring activity shall be notified of design deficiencies which contribute to human error.

APPENDIX D: HFE T&E TECHNIQUE WORKSHEETS

One of the first tasks performed during the development of this guide was the survey for all of the various HFE T&E techniques and tools. As each new technique was "discovered", it was listed along with all of its characteristics. The worksheets in this appendix are the result of that original effort. Although much of the data included in the worksheets is also discussed in the Section 5.0 narrative, the worksheets are included here to assist the user of this guide in making comparisons between each of the techniques and to choose the appropriate one(s) for use.

The following is an explanation of the worksheet form: Under the heading of "T&E Technique", each of the techniques to be evaluated are listed. Across the top are a number of selection evaluation characteristics. The purpose of these characteristics columns is to make evaluative comments as a part of a selection process. That process being to choose the most useful T&E techniques for a given program. Some techniques are obviously better than others for certain types of programs, program stages, or T&E efforts. The following describes in detail what is meant by each of the evaluation characteristics.

a) USAGE:

Specific Programs Used On - A brief list of each of the programs on which this particular T&E technique has been used.

Program Stage Applicability - The stage or phase of a program that is best suited to the use of this technique: future programs such as the VPX, evolving programs such as the F-18, or existing programs such as the P-3.

b) INHERENT FEATURES:

Advantages - That which is particularly useful about this technique as compared to other HFE T&E techniques.

Disadvantages - The drawbacks or limitations of this technique as compared with others.

Implications If Not Used - Significant consequences of what T&E data might "fall through the crack" if this technique is not used.

c) BEST USE:

Data Category - The category of data (qualitative and/or quantitative) that this technique would tend to provide.

Technique Category - The basic category (testing and/or evaluation) for which this technique would be used. For example, some techniques are useful only for gathering data but not for evaluation of that data until an additional process is performed to make the data understandable.

System Use - The use of this technique for all or only a portion of the total system being evaluated. For example, certain techniques may be useful for examining the HFE aspects of a component, but of much less use for a subsystem evaluation, and not of any value for a complete system evaluation.

Task Breadth - The category which indicates the relative quantity of different tasks that may be simultaneously tested by using this technique.

d) RELATIVE PERFORMANCE:

Relative Time to Perform - The time category (short, medium, long) that best describes the time to perform this technique for a given test, as compared to other techniques.

Relative Complexity - The category of relative complexity (simple, average, complex) that best describes this technique as compared to other analysis techniques.

Personnel Required - Estimates as to both the average total manhours required per test (excluding both pre- and post-test time) and the number of HFE T&E observers or evaluators.

Relative Cost - The category that best describes the relative cost (low, medium, high) of this technique as compared to other techniques.

e) PROGRAM INTERFACE REQUIREMENTS:

Input Parameters - The sort of information that is required prior to initiating the use of this technique (e.g., anticipated human performance in terms of time required, based on analysis, or previous test data).

Immediate Outputs or Products - The data that is obtainable from the use of this technique (e.g., operator errors, design criteria compliance, need for special tools) and what form in which the data should be compiled (e.g., report format) and to whom the data should go (Note: See Reference 10 GPTP Guide standardized format).

Coordination Required - Other organizations or support that is required to perform the test (e.g., special arrangements as to approval or security access).

Remarks - Any other pertinent comments in regard to the use of the technique (e.g., special facilities or equipment required or special T&E personnel qualifications).

HFE T&E TECHNIQUES WORKSHEETS

T&E TECHNIQUE	SPECIFIC PROGRAMS USED ON	GENERAL PROGRAM STAGE APPLICABILITY: FUTURE	EVOLVING	EXISTING	ADVANTAGES, DISADVANTAGES, & IMPLICATIONS IF NOT USED
DIRECT CONTINUOUS OBSERVATION	MINUTEMAN (M^2), E-3A, TITAN II INERTIAL GUIDANCE, F-4C, GAM-77		X	X	ADVANTAGES: - OBSERVER FORCED TO LEARN ABOUT SYSTEM-GETS TO KNOW TEST PARTICIPANTS - OBSERVER MAY EVALUATE AS HE RECORDS DATA DISADVANTAGES: - REQUIRES SPECIALIZED OBSERVERS FOR EACH OF THE DIFFERENT TEST CATEGORIES - SINGLE OBSERVER CAN'T LEARN SUFFICIENTLY ABOUT ALL SYSTEM ASPECTS IF NOT USED: - RISK OF MISSING AN OVERALL IMPRESSION OF TEST, AS WELL AS SOME DETAILS THAT WOULD OTHERWISE BE OVERLOOKED
DIRECT SAMPLED OBSERVATION	M^2, E-3A		X	X	SAME AS ABOVE ADVAN. & DISADVANTAGES. A FURTHER DISADVANTAGE IS THE RISK OF MISSING A SIGNIFICANT TEST ITEM AND NOT GETTING THE CORRECT OVERALL TEST IMPRESSION. A FURTHER ADVANTAGE IS THE TIME (AND COST) SAVING FOR THE OBSERVER AS COMPARED TO THE CONTINUOUS OBSERVATION

T&E TECHNIQUE	BEST USE: QUALITATIVE DATA	QUANTITATIVE DATA	TESTING	EVALUATION	TOTAL SYSTEM	SUBSYSTEM	COMPONENTS	SINGLE TASKS	SIMULTANEOUS TASKS	RELATIVE TIME TO PERFORM: SHORT	MEDIUM	LONG	RELATIVE COMPLEXITY: SIMPLE	AVERAGE	COMPLEX	PERSONNEL REQUIRED: MHRS/TEST *	NO. EVALUATORS *	RELATIVE COST: LOW	MEDIUM	HIGH
DIRECT CONTINUOUS OBSERVATION	X		X		X	X	X	X	X		X		X			2/8	2		X	
DIRECT SAMPLED OBSERVATION	X		X		X	X	X	X	X		X		X			1/4	1	X		

T&E TECHNIQUE	INPUT PARAMETERS	IMMEDIATE OUTPUTS OR PRODUCTS	SPECIAL COORDINATION REQUIRED	REMARKS: (SPECIAL FACILITIES/ EQUIPMENT REQ'D OR SPECIAL T&E PERSONNEL QUALIFICATIONS)
DIRECT CONTINUOUS OBSERVATION	BASIC KNOWLEDGE OF SYSTEM PERFORMANCE-INCLUDING OPERATOR PERFORMANCE MOCKUPS OR HARDWARE	TIMELINE VERIFICATION SYSTEM VERIFICATION HUMAN PER. DATA FOR HFE DATA BANK (E.G. OPERATOR ERROR DATA) EVAL. OF SYS. PROBLEMS BIS YELLOW SHEETS		WELL USED TECHNIQUE A SIGNIFICANT PORTION OF ANY TEST OBSERVATION IS THE GATHERING OF HPR DATA. THE FOLLOWING 3 REFS. ARE USEFUL TO DETERMINE DETAILS OF THIS PERFORMANCE MEASURE. 1) McCALPIN, J.P., "INCORPORATING HPR DATA IN SYS. REL. MODELS" ER 7312 (HEL)(AAI CORP), DEC 72. 2) McCALPIN, J.P., "DEV OF A METHODOLOGY FOR OBTAINING HPR DATA FOR A MACHINE EUS 595" TM 6-74 (HEL), FEB. 74. 3) McCALPIN & MILES, "DETERMINING HPR WITH INFANTRY WEAPONS: PART ONE" TM 22-74 (HEL), OCT. 74.
DIRECT SAMPLED OBSERVATION	SAME AS ABOVE	SAME AS ABOVE		MAY TIME SAMPLE ON BASIS OF CRITICAL TASKS OR AT RANDOM

*MIN/MAX

HFE T&E TECHNIQUES WORKSHEETS

METHODOLOGY:
MANUAL DIRECT

THE TECHNIQUE					ADVANTAGES, DISADVANTAGES, & IMPLICATIONS IF NOT USED	BEST USE											RELATIVE TIME TO PERFORM*	RELATIVE COMPLEXITY	PERSONNEL REQUIRED	INPUT PARAMETERS	IMMEDIATE OUTPUTS OR PRODUCTS	COORDINATION	REMARKS:
DESIGN CRITERIA CHECKLIST	M^2,E-3A,A-7, TRAM,TA-7C, WX-70 RADAR, TAV-BA	X	X	X	ADVANTAGES: - DOESN'T REQUIRE EXTENSIVE KNOWLEDGE OF SYSTEM DISADVANTAGES: - USED TO EVALUATE HARDWARE ONLY - OFTEN DESIGN COMPLIANCE IS NOT BINARY CHECKLIST MUST BE DONE THOROUGHLY TO BE USEFUL IF NOT USED: - SIGNIFICANT RISK OF ASSURANCE THAT ITEM IS PROPERLY DESIGNED	X	X	X		X	X			X		X	5/3	1	X	MOCKUPS OR ACTUAL HARDWARE PREVIOUSLY COMPLETED CHECKLISTS FOR SAME EQUIPMENT ITEM KNOWLEDGE OF MIL-SPEC	-DESIGN CRITERIA COMPLIANCE -RECOM. CORRECT'S TO ENGR. -REVIEW HD'W HISTORY -REQUEST DEVIATION TO SPEC. -BIS YEL. SHEET RETEST. OR REDESIGN RECOM. TO ENGR.	NON INTERFERENCE	WELL USED TECHNIQUE SIMILAR TO HFTEMAN (REF. ALSO PS TEST BIOMED. SUPPORT RECORD WHICH EMPHASIZES BIOMEDICAL/LIFE SUPPORT TEST ASPECTS - SAMSO EXHIBIT 65-19 SEPT. 1968) CHECKLISTS ARE OFTEN DEVELOPED BY HFE FOR PARTICULAR PROGRAMS (E.G., NATC CHECKLIST) CHECKLIST ARE GENERALLY RUN FOR STATIC CONDITIONS ONLY HELPS INSURE COMPLIANCE WITH ALL HFE ASPECTS OF ALL SPECS
SPECIFICATION COMPLIANCE SUMMARY SHEET	E-3A		X		ADVANTAGES: - VERIFIES SECTION 4.0 OF SYSTEM SPECS DISADVANTAGES: - TIME CONSUMING IF NOT USED: - RISK OF ASSURANCE THAT ITEM IS DESIGNED PER SPEC	X	X	X	X	X	X	X			X	X	1/4	1	X	SPEC. SEC. 4.0			
T.O. FUNCTIONAL EVALUATION	E-3A, M^2		X		ADVANTAGES: - T.O. VALIDATION DISADVANTAGES: - TIME, COST, ETC. IF NOT USED: - RISK OF ASSURANCE THAT T.O.'S ARE ADEQUATE	X		X				X	X		X	X	1/4	1	X	KNOWLEDGE OF T.O. OPERATOR/ MAINT. PERF. WITH T.O.	TO REV. OR RECOM. TO TECH PUBS GRP.		(REF. ALSO AUTOMATED READIBILITY INDEX (ARI) TO DETERMINE READABILITY DIFFICULTY-POTEMPA, K.W., "A CATELOG OF HUMAN-FACTORS TECHNIQUES FOR TESTING NEW SYSTEMS", AFHRL-TR-68-15, FEB. 69).

*MIN/MAX

HFE T&E TECHNIQUES WORKSHEETS

METHODOLOGY:
MANUAL DIRECT

T&E TECHNIQUE	SPECIFIC PROGRAMS USED ON	APPLICABILITY	ADVANTAGES, DISADVANTAGES, & IMPLICATIONS IF NOT USED	BEST USE	RELATIVE TIME TO PERFORM	RELATIVE COMPLEXITY	PERSONNEL REQUIRED	RELATIVE COST	INPUT PARAMETERS	IMMEDIATE OUTPUTS OR PRODUCTS	SPECIAL COORDINATION REQUIRED	REMARKS: (SPECIAL FACILITIES/ EQUIPMENT REQ'D OR SPECIAL T&E PERSONNEL QUALIFICATIONS)
HUMAN PERFORMANCE RELIABILITY TESTING	STONER RIFLE & MACHINE GUN	X X	ADVANTAGES: - PROVIDES DATA BANK OF HPR'S FOR FUTURE USE - EMPHASIZES OPERATOR ERROR DISADVANTAGES: - MAY EXCLUDE TIME PERFORM. DATA - REQUIRES NUMEROUS SUBJTS. AND REPLICATIONS IF NOT USED: - MUST RELY MORE ON IMPRESSIONS FOR HPR'S RATHER THAN DATA	X X X X X	X	* *		X	- KNOWLEDGE OF OPERATOR PERF. AS WELL AS EQUIPMENT - PROTOTYPE HARDWARE - OPERATOR ERRORS	- ERRORS PER TASK - EVAL. OF SYSTEM PROBLEMS - DATA BANK HPR'S		*REQUIRES CONSIDERABLE TIME AND EFFORT ON THE PART OF PARTICIPANTS AND OBSERVERS
HFTEMAN (CHECK LIST)	US-3A	X X X	ADVANTAGES: - BROAD APPLICABILITY - NO SPECIAL EQUIPMENT - SYSTEMATIC CHECK FOR ANY MILITARY SYSTEM IF NOT USED: - TEST PLANNING BASED ON OTHER RESOURCES	X X X X X X	X	4/16 1	X		KNOWLEDGE OF VOLS. I&II OF MANUAL	ITEMIZED LISTING OF DEFICIENT DESIGN - BIS YEL. SHEETS	NON-INTERFERENCE	AIDS IN - TEST PLANNING & CONDUCT
G-5 ANTHROPOMETER	TAV-8A TA-7C	X X	ADVANTAGES: - GOOD FOR PRACTICAL DIRECT DESIGN CRITERIA COMPLI. (E.G. ESCAPE ENVELOPE) IF NOT USED: - SIGNIFICANT RISK IN TEST. EXTREME ANTHROPOMETRIC LIMITS FOR TOTAL POPULATION OF USERS.	X X X X X	X	1/2 2	X		ACTUAL HRD. OR SOPHIS. MOCKUP	DESIGN ENVEL. VERIF. PILOT/OPER. ACCEPTANCE	MUST NOT INTERFERE WITH OTHER SYS. TSTS.	NAMED AS THE 5TH MODEL OF THE LCDR GRAZONIRE ANTHROPOMETER A COMPOUND GONOMETER WAS DEVELOPED BY L. HITCHCOCK, NADC, TO EVALUATE AIRCRAFT COCKPIT WORKSPACE

*MIN/MAX

HFE T&E TECHNIQUES WORKSHEETS

METHODOLOGY:
MANUAL DIRECT

T&E TECHNIQUE	SPECIFIC PROGRAMS USED ON	APPLICABILITY			ADVANTAGES, DISADVANTAGES, & IMPLICATIONS IF NOT USED	BEST USE									RELATIVE TIME TO PERFORM			RELATIVE COMPLEXITY			PERSONNEL REQUIRED		RELATIVE COST			INPUT PARAMETERS	IMMEDIATE OUTPUTS OR PRODUCTS	SPECIAL COORDINATION REQUIRED	REMARKS: (SPECIAL FACILITIES/ EQUIPMENT REQ'D OR SPECIAL T&E PERSONNEL QUALIFICATIONS)
		[illegible]	[illegible]	[illegible]		QUALITATIVE DATA	QUANTITATIVE DATA	TESTING	EVALUATION	TOTAL SYSTEM	SUBSYSTEM	COMPONENTS	SIMPLE TASKS	COMPLEX TASKS	SHORT	MEDIUM	LONG	SIMPLE	AVERAGE	COMPLEX	[illegible]	[illegible]	LOW	MEDIUM	HIGH				
TERRAIN VISIBILITY DEFINITION	RF-101, RF-4C	X	X	X	ADVANTAGES: - KNOWLEDGE OF PILOT'S (CREWMAN'S) VISUAL ENV. DISADVANTAGES: - TIME & EFFORT TO PERFORM IF NOT USED: - DIFFICULT TO COMPARE VARIOUS DIFFERENT COCKPIT CONFIGURATIONS ON VISION CAPABILITIES		X	X			X					X			X		2 8	2		X		ACTUAL A/C OR HIGH QUAL. MOCKUP	DATA USED TO DET. VISUAL AREA AVAIL TO AIRCREW WHEN A/C IN HORZ. FLT. ATTITUDE	REQS. SPEC TEST SETUP	TECHNIQUE USED TO DETERMINE THE IN-FLIGHT VERTICAL & HORIZONTAL VISUAL ANGLES. REQUIRES A/C OR MOCKUP AND SURVEYOR'S TRANSIT AS WELL AS ENGINEER'S HAND LEVEL
SECONDARY TASK MONITORING	DYNA-SOAR	X	X	X	ADVANTAGES: - WORKLOAD DETERMINED BY TIME AVAILABLE TO PERFORM SECONDARY TASKS DISADVANTAGES: - REQUIRES CONSIDERABLE EFFORT TO SET-UP & MONITOR ALL TASKS IF NOT USED: - WORKLOAD ESTIMATE MUST BE LESS ACCURATE THAN IF USED	X	X	X			X			X		X	X			X	8 40	3			X	SIMULATOR/ MOCKUP OPERATOR PERFORMANCE	DATA TO EVAL. REQ. WORKLOAD E.G. FLT CONTROL MOVEMENTS	SIMULATOR/ MOCKUP INSTALL. OF TASK EQUP. & MONITOR. SENSORS & COMM SET-UP TO PARTICIPANT	USED TO DETERMINE DECREMENT IN MISSION RELATED PERFORMANCE OF SYSTEM OPERATORS AS A RESULT OF INCREASED WORKLOAD THIS TECHNIQUE HAS BEEN RECATEGORIZED AS "AUTOMATIC RECORDING" (DEPENDING ON TEST SETUP) NATC ALONG WITH UNI. OF ILL. WILL BE DOING ADDITIONAL WORK IN RELATION TO THE USE OF THIS GENERAL TECHNIQUE TYPE

*MIN/MAX

METHODOLOGY:
MANUAL DIRECT

THE TECHNIQUE	SPECIFIC PROGRAMS USED ON	DEVELOPMENT PROGRAM PHASE APPLICABILITY: FUTURE	EVOLVING	EXISTING	ADVANTAGES, DISADVANTAGES, & IMPLICATIONS IF NOT USED
INSTRUMENTATION PACKAGES: ENVIRONMENT & PERFORMANCE MEASURING EQUIPMENT IN TWO (2'x2'x3') PACKAGES	TECOM		X	X	ADVANTAGES: - INCLUDES ALL TOOLS THAT CAN BE USED IN HFE NEATLY PACKAGED IN TWO CONTAINERS - FIELD TRANSPORTABLE BATTERY OPERABLE DISADVANTAGES: - COST - LOGISTICS TO TOTE IF NOT USED: - NO SIGNIFICANT IMPACT, ONLY A LOSS OF CONVENIENCE IF NOT USED IN PACKAGE FORM. HOWEVER, MOST INDIVIDUAL PACKAGE ITEMS MUST BE AVAILABLE TO HFE FROM SOME TOOL/EQUIPMENT SUPPLY SOURCE
METHODOLOGY: MANUAL SYS. MEAS.					
SYSTEM RECORD REVIEW - TEST LOGS - MAINTENANCE RECDS. - DEBRIEFING RECDS.	E-3A		X	X	ADVANTAGES: - DOESN'T REQUIRE SPECIAL TEST OR SCHED. DISADVANTAGES: - "CAN'T SEE THE FOREST FOR THE TREES" - RECORDS TEND NOT TO PROVIDE THE EXACT DATA DESIRED IF NOT USED: - NO SIGNIFICANT IMPACT
HUMAN INITIATED FAILURES	E-3A		X	X	ADVANTAGES: - EMPHASIZES OPERATOR ERROR DISADVANTAGES: - OPERATORS TEND NOT TO REPT OWN ERRORS - OBSERVERS MUST BE EXTREMELY KNOWLEDGEABLE OF SYS. PROC. IF NOT USED: - OTHER HFE T&E TECH. MAY BE USED

BEST USE

THE TECHNIQUE	QUALITATIVE DATA	QUANTITATIVE DATA	TESTING	EVALUATION	TOTAL SYSTEM	SUBSYSTEM	COMPONENTS	SINGLE TASKS	SIMULTANEOUS TASKS	RELATIVE TIME TO PERFORM: SHORT	MEDIUM	LONG	RELATIVE COMPLEXITY: SIMPLE	AVERAGE	COMPLEX	PERSONNEL REQUIRED: MANS/TEST*	NO. EVALUATORS	RELATIVE COST: LOW	MEDIUM	HIGH
INSTRUMENTATION PACKAGES		X	X			X	X			X	X			X			2		X	
SYSTEM RECORD REVIEW	X	X	X	X		X	X	X		X	X					.5/4	1		X	
HUMAN INITIATED FAILURES		X	X	X		X	X	X		X						.5/4	1	X		

*MIN/MAX

THE TECHNIQUE	INPUT PARAMETERS	IMMEDIATE OUTPUTS OR PRODUCTS	SPECIAL COORDINATION REQUIRED	REMARKS: (SPECIAL FACILITIES/ EQUIPMENT REQ'D OR SPECIAL T&E PERSONNEL QUALIFICATIONS)
INSTRUMENTATION PACKAGES	HARDWARE OR SHOPISTICATED MOCKUP	COMPARISON TO SPEC. CRITERIA	2 MAN LIFT	THIS IS A "TOOL KIT" OF: SOUND LEVEL METER, VIBRATION METER, THERMOMETER, ASPIRATING PSYCHOMETER, HOT WIRE ANEMOTER, PHOTOMETER, SPOT BRIGHTNESS METER, ANTHROPOMETRY KIT, SHORT & LONG TERM GAS SAMPLERS, WEATHER STATION, & 4 CHANNEL INSTRUMENTATION TAPE RECORDER IN THE ENVIRONMENT CASE; AND A VIDEOTAPE RECORDER SYS. POLAROID XC-70, AUDIO RECORDER, DIGITAL TIMER, MULTIPLE EVENT COUNTER, FORCE & TORQUE GAGES, STEEL TAPES, HAND CALCULATEOR AND INTEGRATED OPS MANUAL IN PERFORMANCE CASE. SOLD BY PERCEPTRONICS WOODLAND HILLS, CALIF.
SYSTEM RECORD REVIEW	-TEST LOGS/ -MAINT RECD/ -DEBRFG. REC.	-MAN/MACH. PROB. -LOGIS. PROB. -TEST PBM. -DEGREE OF TEST SUC. -OPER. ERROR DATA	-ACCESS TO TEST, MNT. & DEBRG. RECORDS	DEPENDING ON SITUATION, THIS TECH. MAY LEAD TO ERRONEOUS INFORMATION AND FRUSTRATION WHEN ONLY TEST LOG & MAINT. RECDS. USED. DEBRF. RECDS. TEND TO BE MORE USEFUL.
HUMAN INITIATED FAILURES	-KNOW. OF SYS. WORK. PART. OPER. TASKS. -FAILURE OR ERROR ANAL. FORMS	-ERROR DATA -RECOM. COR. TO ENG.	CONFER WITH PARTICIPANTS	TECHNIQUE DOES NOT WORK WELL BEC. OF RELUCT. TO REPT. ERROR DATA, OFTEN ERRORS ARE CORRECTED RATHER THAN REPT. NEAR MISTAKES MAY BE REPORTED IF ALMOST MADE

HFE T&E TECHNIQUES WORKSHEETS

METHODOLOGY: MANUAL SYSTEM MEASUREMENTS T&E TECHNIQUE	SPECIFIC PROGRAMS USED ON	[illegible] APPLICABILITY: FUTURE	EVOLVING	EXISTING	ADVANTAGES, DISADVANTAGES, & IMPLICATIONS IF NOT USED	BEST USE: QUALITATIVE DATA	QUANTITATIVE DATA	TESTING	EVALUATION	TOTAL SYSTEM	SUBSYSTEM	COMPONENTS	SINGLE TASKS	SIMULTANEOUS TASKS	RELATIVE TIME TO PERFORM: SHORT	MEDIUM	LONG	RELATIVE COMPLEXITY: SIMPLE	AVERAGE	COMPLEX	PERSONNEL REQUIRED: HFE SPECIALIST*	HFE EVALUATOR	RELATIVE COST: LOW	MEDIUM	HIGH	INPUT PARAMETERS	IMMEDIATE OUTPUTS OR PRODUCTS	SPECIAL COORDINATION REQUIRED	REMARKS: (SPECIAL FACILITIES/ EQUIPMENT REQ'D OR SPECIAL T&E PERSONNEL QUALIFICATIONS)
TEST PARTICIPANT HISTORY RECORD	M^2		X	X	ADVANTAGES: - PARTICIPANT HISTORY MAY IMPACT TEST RESULTS DISADVANTAGES: - OR NO IMPACT, THEREFORE WASTED TIME AND EFFORT IF NOT USED: - GENERALLY LITTLE IMPACT	X	X		X	X	X	X	X	X	X			X			.5	1	X			INTERVIEW TEST PARTIP.	ASSISTS HFE IN PRFM. TST EVAL.	BEST COMP. BEFORE TEST	(REF. SAMSO EXHIBIT 68-19 SEPT. 1968)
METHODOLOGY: MANUAL INDIRECT																													
INDIRECT OBSERVA. INTERVIEWS	WX-50, A-7 TRAM, M^2, E-3A, F-4C, IM-99A		X	X	ADVANTAGES: - PROVIDES DATA FROM SYS. EXPERTS- OFTEN THE BEST DATA BY FAR DISADVANTAGES: - DOES NOT SUBSTITUTE FOR SOME AMOUNT OF DIRECT OBSERVATION - IF POSSIBLE IF NOT USED: - RISK OF OVERLOOKING POSSIBL. BEST DATA SOURCE	X		X		X	X	X		X	X			X			.5/1	1	X			TEST PARTI. REACTIONS TO SPECIFIC Q'S	EVAL. DATA BIS YEL. SHEET	ARRANGE TIME FOR INTER. IN TIME PER AFTER TEST	INTERVIEW FORMAT IS SOMEWHAT LIKE A CHECKLIST WITH THE ADDED FEA. OF APPROP. NARRATIVE (REF FOLLOWING LISTED PS POST TEST INTERVW/ANAL. RECORD)
QUESTIONNAIRES	E-3A, WX-50, A-7TRAM, AGCA		X	X	ADVANTAGES: - MAY BE USED AS CHECKLIST TO COVER ALL ASPECTS OF SYS. TEST - PROVIDES DATA FROM SYS. EXPERTS - TRAINS THE PARTICIPANTS AS TO WHAT HFE ASPS. ARE SIG. - MAY BE USED WITH LG. GRPS. - MAY BE FORMATTED FOR RAPID DATA REDUCTION DISADVANTAGES: - DOES NOT SUB. FOR DIRECT OBSERV. IF NOT USED: - RISK OF MISSING A CERTAIN AMOUNT OF DATA - EITHER INTERVIEWS OR QUESTIONNAIRES SHOULD BE USED	X		X		X	X	X	X	X	X	X		X			.5/1	1	X			TEST PARTI. REACTION TO SPECIFIC Q'S	EVAL. DATA BIS. YEL SHEET	ARRANGE TIME FOR PARTI. TO FILL OUT QUEST.	- SHOULD NOT BE OVERUSED ON SAME PARTICIPANT - MAY MAKE PAIRED QUESTION COMPARISONS TO KNOWN SYS. FOR BETTER MORE USEFUL RESPONSES (REF. FUNCT. DES. INVENTORIES ON NEXT SHEET)

*MIN/MAX

HFE T&E TECHNIQUES WORKSHEETS

METHODOLOGY:
MANUAL INDIRECT

THE TECHNIQUE	SPECIFIC PROGRAMS USED ON	STAGE APPLICABILITY			ADVANTAGES, DISADVANTAGES, & IMPLICATIONS IF NOT USED	BEST USE											RELATIVE TIME TO PERFORM			RELATIVE COMPLEXITY		PERSONNEL REQUIRED		RELATIVE COST		INPUT PARAMETERS	IMMEDIATE OUTPUTS OR PRODUCTS	REQUIRED COORDINATION	REMARKS: (SPECIAL FACILITIES EQUIPMENT REQ'D OR SPECIAL T&E PERSONNEL QUALIFICATIONS)
FUNCTIONAL DESCRIPTION INVENTORIES (FDI'S)	P-3C, E-2C, S-3A		X	X	ADVANTAGES: - MAY BE USED AS A CHECKLIST TO COVER ALL ASPECTS OF SYS. TEST - PROVIDES DATA FROM SYS. EXPERTS - TRAINS THE PARTICIPANTS AS TO WHAT HFE ASPECTS ARE SIG. - EXTREMELY THOROUGH DISADVANTAGES: - TIME AND EFFORT TO DEV. QUEST. - TIME AND EFFORT TO COM. QUEST. - CREWMAN AVAIL. IF NOT USED: - USE OTHER Q'S & INTERVS.	X		X	X	X	X	X	X				X		X		2/8	1		X	X	KNOWLEDGE OF SYS/OPER. PROC. & QUES METH.	CREW WORK-LOAD OPIN. & ATTITUDES BIS YEL SHEET	TIME FOR CREW TO FILL OUT FDI'S PERMISSION TO INTERV. CREWMEN	THE FDI IS A SPECIAL CASE QUES.
PERSONNEL ACTIVITY ANALYSIS RADIO-SYSTEM (PAARS) - QUEST.	B-52, 407L			X	ADVANTAGES: - OBTAINS MOST OBJECTIVE RESPONSE TO QUESTIONS WHILE DATA IS FRESH IN MIND OF TECH. - USED WITH TAPE RECORDER SO THAT DATA MAY BE REV. - SAVES TRAVEL FOR HFE DISADVANTAGES: - HFE CANNOT SEE THE PROB. - LIMITED TO GND BASED A/C MAIN. TASKS - PART. MUST REM. TO USE - REQ. FULL TIME USE OF HFE IF NOT USED: - OBTAIN DATA FROM OTHER TECH.	X	X	X	-	-X	X	X	X		X		X	X			2/*8	1			X	- DIRECT RES. FROM TECH.	EVAL. DATA OPER. ERROR DATA	PERMISSION FROM SEC. AND MAIN. CONTROL TO USE SYS.	ESSENTIALLY A DIRECT OBSERVA. QUEST. TECH. USES 2-WAY RADIO BETWEEN ONE HFE AND SEVERAL MAIN. TECH'S OR CREWS. REQS. 2-WAY RADIOS AND TAPE RECORDER (REF. SOUND TAPE RECORD. TECH'S ON FOLLOWING PAGES.)

*MIN/MAX

*LONG TIME TO PERFORM FOR HFE TO MAN HIS POST AT RADIO

HFE T&E TECHNIQUES WORKSHEETS

METHODOLOGY: MANUAL INDIRECT T&E TECHNIQUE	SPECIFIC PROGRAMS USED		ADVANTAGES, DISADVANTAGES, & IMPLICATIONS IF NOT USED	BEST USE		RELATIVE COMPLEXITY*			INPUT PARAMETERS	IMMEDIATE OUTPUTS OR PRODUCTS	SPECIAL COORDINATION REQUIRED	REMARKS: (SPECIAL FACILITIES/ EQUIPMENT REQ'D OR SPECIAL T&E PERSONNEL QUALIFICATIONS)
COOPER/HARPER SCALE	TEST FLIGHT	X	ADVANTAGES: - A RELATIVELY STANDARD MEANS TO EVAL. A/C HANDLING QUAL. - INFO COMES FROM SYS. EXP. DISADVANTAGES: - MAY BE MISUSED BY ENGRS. - USEFUL FOR PILOT EVAL. OF FLT. HANDLING QUAL. ONLY IF NOT USED: - PILOT COMMENTS MAY VARY WIDELY AS TO A/C FLT HANDLING QUALITIES	X	X X X X X X X	.5/4	1	X	PILOTS REAC. TO SPEC. FLT. HANDLING QUAL. Q'S	-EVAL. DATA -DATA TO ENG. DESN FOR DES. IMP.	ARRANGE TIME FOR PILOT TO EVAL. FLT HAND. QUAL. EDUCATE PILOT TO USE OF SCALE	MAY BE PERFORMED WITHOUT HFE T&E PERSONNEL
PROBLEM INCIDENT REPORTS OR UNPLAN. EVENT RECORDS	E-3A	X	ADVANTAGES: - DATA SOURCE FROM SYS. EX. - FORCES TEST DOCU. - MAY BE SELF SUSTAINING DISADVANTAGES: - NOT SUFF. BY ITSELF. OTHER HFE T&E TECH. ARE NEEDED - LESS IMPORTANT TEST ASPECTS NOT INCLUDED IN THIS REPORT IF NOT USED: - HFE HAS TO TRY HARDER TO GO OUT TO FIND THE PROB. ON HIS OWN	X	X X X X X X X X	.5/1	1	X	PARTI. REAC. TO TEST SQUAWK SHEET	-IDENT. OF UNSAT. COND. -RECOM. CORR. TO ENG.	ARRANGE TIME OR PROCED FOR PARTI. TO FILL OUT FORM IF POSS.	THIS IS A WELL USED FORM OFTEN CALLED A SQUAWK SHEET

*MIN/MAX

METHODOLOGY:
AUTOMATIC RECORDING

T&E TECHNIQUE	SPECIFIC PROGRAMS USED ON	GENERAL PROGRAM PHASE APPLICABILITY: [illegible]	[illegible]	[illegible]	ADVANTAGES, DISADVANTAGES, & IMPLICATIONS IF NOT USED	BEST USE: QUALITATIVE DATA	QUANTITATIVE DATA	TESTING	EVALUATION	TOTAL SYSTEM	SUBSYSTEM	COMPONENTS	SINGLE TASKS	SIMULTANEOUS TASKS	RELATIVE TIME TO PERFORM: SHORT	MEDIUM	LONG	RELATIVE COMPLEXITY: SIMPLE	AVERAGE	COMPLEX	PERSONNEL REQUIRED: DATA COLLECTORS*	EVALUATORS*	RELATIVE COST: LOW	MEDIUM	HIGH	INPUT PARAMETERS	IMMEDIATE OUTPUTS OR PRODUCTS	SPECIAL COORDINATION REQUIRED	REMARKS: (SPECIAL FACILITIES/ EQUIPMENT REQ'D OR SPECIAL T&E PERSONNEL QUALIFICATIONS)
MOTION PICTURES	ARMY HELBAT, SMALL ARMS, APOLLO, MINUTEMAN		X	X	ADVANTAGES: - PERMANENT RECORD WHICH MAY BE REVIEWED - DECREASES OBSERVER ERRORS - MAY BE USED IN HAZARDOUS AREAS (REMOTE) - MAY BE USED FOR DESIGN REVIEWS - PERMITS REPEATED OBSERVATIONS (AND SLOW MOTION) - TRAINING AID DISADVANTAGES: - COST & TIME TO PROCESS - MAY MAKE PARTICIPANTS SLIGHTLY SELF CONSCIOUS - SPECIAL PERSONNEL, EQUIPMENT & COORDINATION IF NOT USED: - VIDEO TAPE IS A GOOD SUBSTITUTE, ALTHOUGH VIDEO SLOW MOTION IS MORE EXPENSIVE	X	X	X	X	X	X	X	X	X		X			X		1-4	2			X	- ACTUAL TST AND PARTI. - LIMITED KNOWLEDGE OF SYS. PERF. - OPERATOR/ EQUIP. PERF.	- DOC. TO V&V - TIME LINE VERIFI.	SPEC. PERMISSION TO USE EQUIP. SCHED. OF CAMERA/ CAMERAMAN SPECIAL POSITIONING OF EQUIPMENT MAY REQ. "INTERFERENCE BASIS TST"	- MAY REQUIRE SPECIAL LIGHTING - MAY REQUIRE CAMERAMAN - REQUIRES FILM, CAMERA, PROJECTION EQUIPMENT, POWER SOURCE
SOUND TAPES	M^2, E-3A		X	X	ADVANTAGES: - ALL OF THE ABOVE, PLUS: - LONGER RECORD TIME - MAY RECORD MULTIPLE COMM'S - PRECISE NOTES LESS CRITICAL - REQUIRES NO TIME TO PROC. - MAY RECORD TIME WITH ATTACH. DISADVANTAGES: - MAY MAKE PARTICIPANTS SLIGHTLY SELF CONSCIOUS - BACKGROUND NOISE MAY DISTORT RECORDING IF NOT USED: - MAKES THE USE OF GOOD NOTES ALL THE MORE IMPORT.	X	X	X	X	X	X	X	X	X	X			X			1-2	1	X			SAME AS ABOVE	SAME AS ABOVE	PERMISSION TO USE EQUIPMENT	

*MIN/MAX

HFE T&E TECHNIQUES WORKSHEETS

METHODOLOGY: AUTOMATIC RECORDING

T&E TECHNIQUE	SPECIFIC PROGRAMS USED ON	SYSTEM APPLICABILITY: FUTURE	SYSTEM APPLICABILITY: EVOLVING	SYSTEM APPLICABILITY: EXISTING	ADVANTAGES, DISADVANTAGES, & IMPLICATIONS IF NOT USED	BEST USE: QUALITATIVE DATA	BEST USE: QUANTITATIVE DATA	BEST USE: TESTING	BEST USE: EVALUATION	BEST USE: TOTAL SYSTEM	BEST USE: SUBSYSTEM	BEST USE: COMPONENTS	BEST USE: SINGLE TASKS	BEST USE: SIMULTANEOUS TASKS	RELATIVE TIME TO PERFORM: SHORT	RELATIVE TIME TO PERFORM: MEDIUM	RELATIVE TIME TO PERFORM: LONG	RELATIVE COMPLEXITY: SIMPLE	RELATIVE COMPLEXITY: AVERAGE	RELATIVE COMPLEXITY: COMPLEX	PERSONNEL REQUIRED: MAN/TEST*	PERSONNEL REQUIRED: NO. EVALUATORS*	RELATIVE COST: LOW	RELATIVE COST: MEDIUM	RELATIVE COST: HIGH	INPUT PARAMETERS	IMMEDIATE OUTPUTS OR PRODUCTS	SPECIAL COORDINATION REQUIRED	REMARKS: (SPECIAL FACILITIES/ EQUIPMENT REQ'D OR SPECIAL T&E PERSONNEL QUALIFICATIONS)
VIDEO TAPES	V-15, F-4E (AN/APQ RADAR, MARTIN BAKER MARK H7 ROCKET EJECTION SEAT & ROCKEYE MK20 BOMB)		X	X	ADVANTAGES: - PERMANENT RECORD WHICH MAY BE REVIEWED - DECREASES OBSERVER ERRORS - MAY BE USED IN HAZARDOUS AREAS (REMOTE) - PERMITS REPEATED OBSERV. - TRAINING AID - NO TIME TO PROCESS - RECORDS TIME WITH ATTACH. DISADVANTAGES: - REQ. SPECIAL PERSONNEL, EQUIP, & COORDINATION - SEVERAL K$ FOR RECORDER, CAMERA ZOOM LENS, MONITOR TRIPOD, LIGHTS - SLOW MOTION SHOTS EXPENS. IF NOT USED: - MAY USE MOVIE FILM	X	X	X	X	X	X	X	X	X	X	X			X		1-8	2			X	ACTUAL TEST & PARTICI. KNOWLEDGE OF SYS. PERF. OPERATOR/ EQUIP. PERFORMANCE	DOCUMEN. TO V&V TIME LINE VERIFI.	SPECIAL PERMISSION TO INSTALL EQUIPMENT SCHEDULE OF VIDEO EQUIP. & CAMERMAN MAY REQ. INTERFER. BASIS TST.	MAY REQ. SPECIAL LIGHTING MAY REQ. CAMERAMAN MAY BE USED WITH SOUND TAPE
PHOTOGRAPHY	MINUTEMAN, F-4C, E, & SAME RELATED SUBSYS. INDICATED ABOVE		X	X	ADVANTAGES: - SAME AS FIRST FIVE LISTED ABOVE - MAY BE USED IN REPORTS DISADVANTAGES: - REQ. EQUIPMENT AND COORD. - REQ. NOTATION AS TO DETAILS OF EACH PHOTO IF NOT USED: - MOVIE FILM OR LOTS OF WRITING BY HFE TEST EVALUATOR	X	X	X	X	X	X	X	X		X			X			1-1	1	X	X		ACTUAL TST. & PARTICI.	DOCUMEN.	PERMISSION TO USE EQUIP.	- MAY REQUIRE CAMERAMAN AND TRIPOD

*MIN/MAX

HFE T&E TECHNIQUES WORKSHEETS

METHODOLOGY: AUTOMATIC RECORDING

T&E TECHNIQUE	SPECIFIC PROGRAMS USED ON	SYSTEM APPLICABILITY			ADVANTAGES, DISADVANTAGES, & IMPLICATIONS IF NOT USED	BEST USE									RELATIVE TIME TO PERFORM			RELATIVE COMPLEXITY			PERSONNEL REQUIRED		RELATIVE COST			INPUT PARAMETERS	IMMEDIATE OUTPUTS OR PRODUCTS	SPECIAL COORDINATION REQUIRED	REMARKS: (SPECIAL FACILITIES/ EQUIPMENT REQ'D OR SPECIAL T&E PERSONNEL QUALIFICATIONS)
		FUTURE	EVOLVING	EXISTING		QUALITATIVE DATA	QUANTITATIVE DATA	TESTING	EVALUATION	TOTAL SYSTEM	SUBSYSTEM	COMPONENTS	SINGLE TASKS	SIMULTANEOUS TASKS	SHORT	MEDIUM	LONG	SIMPLE	AVERAGE	COMPLEX	MFR/TEST *	NO. EVALUATORS	LOW	MEDIUM	HIGH				
EVENT RECORDING	F-4E (SAME RELATED SUBSYS. AS INDI. ON PREV. PGE)		X	X	ADVANTAGES: - PERMANENT RECORD WHICH MAY BE REVIEWED - MAY BE USED FOR EIGHT SIMUL. EVENTS - DATA MAY BE REDUCED IMMED. DISADVANTAGES: - REQ. TEST WITH SEVERAL DIF. TASK/TIME REQMTS. TO BE USEFUL - COST AS COMPARED TO STOPWATCH - EASE OF USE AS COMPARED TO STOP WATCH IF NOT USED: - USE OPREDS OR STOPWATCH OR DATAMYTE 900		X	X	X		X	X	X	X	X	X			X		1/8	1		X		TIME PERF. OF PARTICI. KNOWLED. OF OPER. PERF. OPERATOR/ EQUIP. PER.	DESIGN CRITERIA COMPLIANCE-TIME DOCUMENTA. EVALUATION CONTROL ACTIONS		- REQ. TEST WITH SEVERAL TIME CRITICAL EVENTS THAT NEED VERIFI. TO JUSTIFY USE OVER STOPWATCH
OPREDS-OPERATIONAL PERFORMANCE RECORDING AND EVALUATION	NTDS CIC PERF.		X	X	ADVANTAGES: - TRAINING AID - RECORDS ALL OPER. ACTIONS, CONSOLES, CONSOLE MODE, TIME OF EACH ACTION, LINK 11 TRACK NO'S, OWN SHIP TRACK NO'S, NO OF ILLEG. ACTIONS, DATA, TIME, OBSER ETC. - PORTABLE SYSTEM - DATA REDUCTION QUICKLY PER - OBSERVER NEED NOT BE PRES. DISADVANTAGES: - PROVIDES MORE DATA THAN EVALUATOR CAN USE IF NOT USED: - USE DATAMYTE 900 OR STOPWATCH		X	X	X		X	X	X	X	X	X				X	*	1		X		NTDS DATA TO AN/UYK-7 FROM OPERA. CONSOLE ACTIONS	PRINTOUT OF 1. CONSOLE ID 2. CONS MODE 3. ACTION ID 4. FUNC. CODE 5. FUNC. CODE CONTENT 6. ACTION TIME 7. LINK 11 TRACK NOS 8. OWN SHIP TRACK NO. 9. NO. OF ILLEG. ENTRIES 10. IDENTIFIER INFO -OUTPUT IN ENGLISH -TIMES -CURVES -HISTOGRAMS -ETC. ETC.	PRACT. NONE	CONSISTS OF LINE TAP FOR SIGNAL TO DRS, COMPUTER CONSOLE INTERFACE UNIT (CCIU) AND INCREMENTAL TAPE RECORDER UNIT (ITRU) DEVELOPED BY BARTON ASSOC. WITH JANUS ASSOC. FOR NELC, SAN DIEGO DATA COMPATABLE WITH IBM 360 - OUTPUT IN ENGLISH SIMILAR TO ONLINE INTERACTIVE TECHNIQUES

*MIN/MAX

*NO EVALUATOR LIMIT

HFE T&E TECHNIQUES WORKSHEETS

METHODOLOGY:

AUTOMATIC PHYSIOLOGICAL

T&E TECHNIQUE	SPECIFIC PROGRAMS USED ON	PROGRAM APPLICABILITY: FUTURE	EVOLVING	EXISTING	ADVANTAGES, DISADVANTAGES, & IMPLICATIONS IF NOT USED	BEST USE: QUALITATIVE DATA	QUANTITATIVE DATA	TESTING	EVALUATION	TOTAL SYSTEM	SUBSYSTEM	COMPONENTS	SINGLE TASKS	SIMULTANEOUS TASKS	RELATIVE TIME TO PERFORM: SHORT	MEDIUM	LONG	RELATIVE COMPLEXITY: SIMPLE	AVERAGE	COMPLEX	PERSONNEL REQUIRED: MANS/TEST*	NO. EVALUATORS	RELATIVE COST: LOW	MEDIUM	HIGH	INPUT PARAMETERS	IMMEDIATE OUTPUTS OR PRODUCTS	SPECIAL COORDINATION REQUIRED	REMARKS: (SPECIAL FACILITIES/ EQUIPMENT REQ'D OR SPECIAL T&E PERSONNEL QUALIFICATIONS)
PHYSIOLOGICAL INSTRUMENTATION	APOLLO GEMINI MERCUTY	X	X	X	ADVANTAGES: - MAY BE MONITORED REMOTELY AWAY FROM AREA OF TEST - PERMANENT RECORDS EASILY MAINTAINED DISADVANTAGES: - LIMITS MOBILITY OF PARTI. - REQ. EXTENSIVE SETUP IF NOT USED: - DIRECT OBSERVA. OF PARTI. IS A POOR SUB. IF PHYSIOL IS REALLY THE TESTED ITEM		X	X			X		X	X	X	X	X			X	.5/2	*			X	PARTICIPANTS PHYSIOLOGI. PARAMETERS, E.G.:HEART RATE,BLOOD PRES. RESPIRATION, GSR,EEG,EKG, BODY TEMP.	DATA FOR MEDICAL EVALUATION	-MEDICAL APPROVAL -TEST RUN ON "INTERFERENCE BASIS"	EQUIP. REQD: SENSORS, TRANS/ RECEIVER, AMPLIFIER, RECORDER REQ. MEDICAL PERSONNEL FOR PROPER EVAL. AND TECHNS. TO SET UP AND MAINTAIN EQUIP.
PHYSICAL MEASUREMENT a) VOICE MONITORING	NITE CARR LANDINGS		X	X	ADVANTAGES: - MAY INDICATE PROB. NO OTHER TECH. WILL REVEAL DISADVANTAGES: - REQ. SPECIAL EQUIP. & EVAL. IF NOT USED: - QUESTIONNAIRES & INTERV. ARE A SUB. TECH.			X	X		X		X	X		X				X	.5/2	1		X	X	PARTICIPANTS VOICE KNOWLEDGE OF TASKS BEING PERFORMED	DATA FOR EVAL. OF STRESS & STRESS CAUSING TASKS		EXPRMTL. TECH. - REQS. LIE DETECTOR EQUIP. FOR MONITORING OF PSYCH. STRESS REQS. TRAINED EVALUATORS
b) OCULOMETRY			X	X	ADVANTAGES: - THE IDEAL WAY TO DO OR TST LINK ANALYSIS DATA DISADVANTAGES: - COST & EFFORT FOR SETUP - SOMEWHAT EXPERIMENTAL IF NOT USED: - QUESTIONNAIRES AND INTER. MAY SUBSTITUTE		X	X	X		X	X		X		X				X	1/4	2			X	PARTICIPANTS EYE MOVEMENT AT MOCKUP OR HARDWARE CONSOLE/COCKPIT	-LINKS -DWELL TIME -NO. OF CONTACTS -PROB. OF NEXT. CONTACT	-INTERFER. BASIS OR OWN LAB TEST	(REF NASA CR-144951, HONEYWELL, BOSTON) (REF NASA TMX-3344, JIM WISE) REQ. TRAINED OBSERVERS. CAPABILITIES: 1/2° at 30", 60° HORZ, 30° UP, 10° DOWN WHITAKER ALSO MAKES A UNIT

*MIN/MAX

*EXTREMELY VARIABLE

METHODOLOGY: AUTOMATIC PHYSIOLOGICAL T&E TECHNIQUE	SPECIFIC PROGRAMS USED ON	GENERAL PROGRAM STAGE APPLICABILITY: FUTURE	EXISTING	EXISTING	ADVANTAGES, DISADVANTAGES, & IMPLICATIONS IF NOT USED	BEST USE: QUALITATIVE DATA	QUANTITATIVE DATA	TESTING	EVALUATION	TOTAL SYSTEM	SUBSYSTEM	COMPONENTS	SINGLE TASKS	SIMULTANEOUS TASKS	RELATIVE TIME TO PERFORM: SHORT	MEDIUM	LONG	RELATIVE COMPLEXITY: SIMPLE	AVERAGE	COMPLEX	PERSONNEL REQUIRED: MHRS/TEST *	NO. EVALUATORS	RELATIVE COST: LOW	MEDIUM	HIGH	INPUT PARAMETERS	IMMEDIATE OUTPUTS OR PRODUCTS	SPECIAL COORDINATION REQUIRED	REMARKS: (SPECIAL FACILITIES/ EQUIPMENT REQ'D OR SPECIAL T&E PERSONNEL QUALIFICATIONS)
PHYSICAL MEASUREMENT c) ANTHROPOMETRY	MINUTEMAN	X	X	X	ADVANTAGES: - DETERMINES HOW CLOSE SUBS. ARE TO REQ. POPULATION DISADVANTAGES: - SUBJECTS MAY NOT BE REPRESENTATIVE OF REQUIRED POPULATION IF NOT USED: - MUST GUESS THE POPULATION FIT (RISKY)		X	X	X		X				X	X		X	X		*	1	X			PARTICIPANTS	COMPARE ANTHROP. DATA	FINDING RANGE OF TEST PARTI AND AREA TO PERFORM MEASURE.	REQ. SOME SPECIAL ANTHROPOMETRIC MEASURING EQUIP. AND MINIMAL TRAINING OF HFE T&E PERSONNEL
METHODOLOGY: SIMULATION																													
CREW STATION GEOMETRY EVALUATION MODEL (CGE)	UTTAS, A-7	X	X		ADVANTAGES: - COMPUTER SIMULATION OF COCKPIT GEOMETRY PROBLEMS - WORKS DYNAMIC PROBLEMS - LARGE DATA BANK POSSIBLE - WILL OPTIMIZE PROBLEM SOL. - WORKS ALL PERCENTILES - TRUE ANTHROPOMETRIC MODEL DISADVANTAGES: - BATCH MODE ONLY - COMPLEXITY: REQ. TRAINING - COST AND TIME TO USE IF NOT USED: - USE CAR OR PAPER ANALYSIS WITH DRAWINGS OR MOCKUP ANALYSIS		X	X	X		X		X	X			X			X	*	2			X	COCKPIT GEO. TASK DATA	-REACH ENV. -PHYSICAL INTERFER. -VISUAL INTER. -SPEC COMPLIANCE -ANIMATED TASK MOTION		FORTRAN AND CDC 6600 COMPUTER AND APPROPRIATE PRINTOUT AND CALCOMP PLOTTERS OR CRT TERMINAL DISPLAY -REQ. EXTENSIVE USE OF PROGRAMMERS -CGE IS MORE OF A DESIGN TECH. THAN A T&E TECH.

*MIN/MAX

*EXTREMELY VARIABLE

HFE T&E TECHNIQUES WORKSHEETS

METHODOLOGY:

SIMULATION

THE TECHNIQUE	SPECIFIC PROGRAMS USED ON	APPLICABILITY: [illegible]	APPLICABILITY: [illegible]	APPLICABILITY: [illegible]	ADVANTAGES, DISADVANTAGES, & IMPLICATIONS IF NOT USED	BEST USE: QUALITATIVE DATA	BEST USE: QUANTITATIVE DATA	BEST USE: TESTING	BEST USE: EVALUATION	BEST USE: TOTAL SYSTEM	BEST USE: SUBSYSTEM	BEST USE: COMPONENTS	BEST USE: SINGLE TASKS	BEST USE: [illegible] TASKS	RELATIVE TIME TO PERFORM: SHORT	RELATIVE TIME TO PERFORM: MEDIUM	RELATIVE TIME TO PERFORM: LONG	RELATIVE COMPLEXITY: SIMPLE	RELATIVE COMPLEXITY: AVERAGE	RELATIVE COMPLEXITY: COMPLEX	PERSONNEL REQUIRED: [illegible]	PERSONNEL REQUIRED: [illegible] EVALUATOR	RELATIVE COST: LOW	RELATIVE COST: MEDIUM	RELATIVE COST: HIGH	INPUT PARAMETERS	IMMEDIATE OUTPUTS OR PRODUCTS	SPECIAL COORDINATION REQUIRED	REMARKS: (SPECIAL FACILITIES/ EQUIPMENT REQ'D OR SPECIAL T&E PERSONNEL QUALIFICATIONS)
CREWSTATION ASSESSMENT AND REACH (CAR)	F-18 REACH, A-7	X	X		ADVANTAGES: - LOWER RELATIVE COST - INTERACTIVE - COMPUTER SIMULATION OF COCKPIT GEOMETRY PROB. DISADVANTAGES: - NOT DYNAMIC - GIVES ONLY ANSWERS, NOT POSSIBILITIES - WILL NOT OPTIMIZE - NOT COMPLETELY ANTHROPOM IF NOT USED: - USE CGE OR PAPER ANALYSIS WITH DRAWINGS, OR MOCKUP ANALYSIS		X	X	X		X		X			X			X		*	2		X		COCKPIT GEOMETRY TASK DATA	-PHYSICAL REACH -VISUAL INTER. -SPEC. COMPLIANCE		-FORTRAN AND CDC 6600 AND APPROPRIATE PRINTOUT -REQUIRES PROGRAMMER - CAR IS MORE OF A DESIGN TECH. THAN A T&E TECH.
COMPUTERIZED ACCOMODATED PERCENTAGE EVALUATION (CAPE) MODEL	VTAS	X	X	X	ADVANTAGES: - TESTS/VALIDATES COCKPIT (OR OTHER) GEOMETRY TO ACCOMODATE RANGE OR CREWMEN DISADVANTAGES: - REQ. TRAINING TO USE - DESIGN CRITERIA DOES NOT EXIST THAT ALLOWS CORRECT 90% ACCOMMODATION IF NOT USED: - MAY USE SPECIALLY SELECT. SUBJECTS WHO APPROACH 5TH, 95TH PERCENTILE DIMEN. - USE ESTABLISHED DESIGN CRITERIA AND WAIVE 90% ACCOMMO. REQ.		X	X	X		X					X			X		*	2		X		COCKPIT GEOMETRY KNOWLEDGE OF SPEC. REQ.	% TILE ACCOMMOD.		USES BATCH FORTRAN WITH SUPER FORTRAN OPTION REQUIRES PROGRAMMER AND/OR SPECIAL USER TRAINING

*MIN/MAX

*ANALYSIS TIME IN MAN WEEKS

METHODOLOGY:
SIMULATION

T&E TECHNIQUE	SPECIFIC PROGRAMS USED ON	GENERAL SYSTEM STAGE APPLICABILITY: FUTURE	EVOLVING	EXISTING	ADVANTAGES, DISADVANTAGES, & IMPLICATIONS IF NOT USED	BEST USE: QUALITATIVE DATA	QUANTITATIVE DATA	TESTING	EVALUATION	TOTAL SYSTEM	SUBSYSTEM	COMPONENTS	SINGLE TASKS	SIMULTANEOUS TASKS	RELATIVE TIME TO PERFORM: SHORT	MEDIUM	LONG	RELATIVE COMPLEXITY: SIMPLE	AVERAGE	COMPLEX	PERSONNEL REQUIRED: MAX/TEST*	NO. EVALUATORS	RELATIVE COST: LOW	MEDIUM	HIGH	INPUT PARAMETERS	IMMEDIATE OUTPUTS OR PRODUCTS	SPECIAL COORDINATION REQUIRED	REMARKS: (SPECIAL FACILITIES/ EQUIPMENT REQ'D OR SPECIAL T&E PERSONNEL QUALIFICATIONS)
FIELD OF VIEW EVALUATION APPARATUS (FOVEA)	F-18 MOCKUP		X	X	ADVANTAGES: - PROVIDES EXCELLENT COMPARISON WITH DESIGN REQ. DISADVANTAGES: - COST OF COMPUTER AND PLOTTERS FOR OUTPUT IF NOT USED: - MAY USE PHOTOGRAPHS FROM EYE REF. PT. - MAY USE SPECIALLY SELEC. SUB. FOR THEIR EVALUATIONS - USE CAFES CAD		X	X		-	X					X				X	2/8	2			X	KNOWLEDGE OF SPEC. COCKPIT/ MOCKUP	DRAWING OF PILOT FLD. OF VIEW TO COMPARE WITH REQ. BIS YEL. SHEET		CAMERA & CAMERA CONTROL DEVICE FOR INPUT TO COMPUTER
ONLINE INTERACTIVE	C-14, E-3A	X	X		ADVANTAGES: - CAPABLE OF RECORD. ALL PARTICI. ACTIONS, TIME OF EACH ACT., CAUSE OF ACT., ERRORS - TRAINING AID - CHEAPER THAN PROTOTYPE - DATA RED. QUICKLY PERF. - OBSERVER NEED NOT BE PRES. - MAY PROVIDE GRAPHIC OUTPT. - MAY RECORD AND PLAYBACK DISPLAY DISADVANTAGES: - REQ. INTERACTIVE (ONLINE) COMPUTER TIME, THEREFORE VERY EXPENSIVE - REQ. EXPENSIVE PROGRAMS (OR PROG. NEEDS) FOR SIM. - TOO EXPENSIVE TO USE FOR SHORT TSTS. IF NOT USED: - USE DATAMYTE 900 OR STOP-WATCH		X	X	X	_	X	X	X	X		X				X	5*/8	1			X	TEST PARTICI. ACTIONS PRELIMINARY OPERATOR PROCEDURES	PRINTOUT: ACTIONS TIMES ERRORS DISPLAY PLAYBACK	ARRANGE COMPUTER TIME	-SIMILAR TO OPREDS WITH EXCEPTION OF SIMULATION RATHER THAN ACTUAL HARDWARE - REQ. SOPHISTICATED COMPUTER, PROGRAMMERS AND PROTOTYPE OR HOT MOCKUP CONSOLE

*MIN/MAX

*EXTREMELY VARIABLE